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ECE

ACE

PM 1 (B)

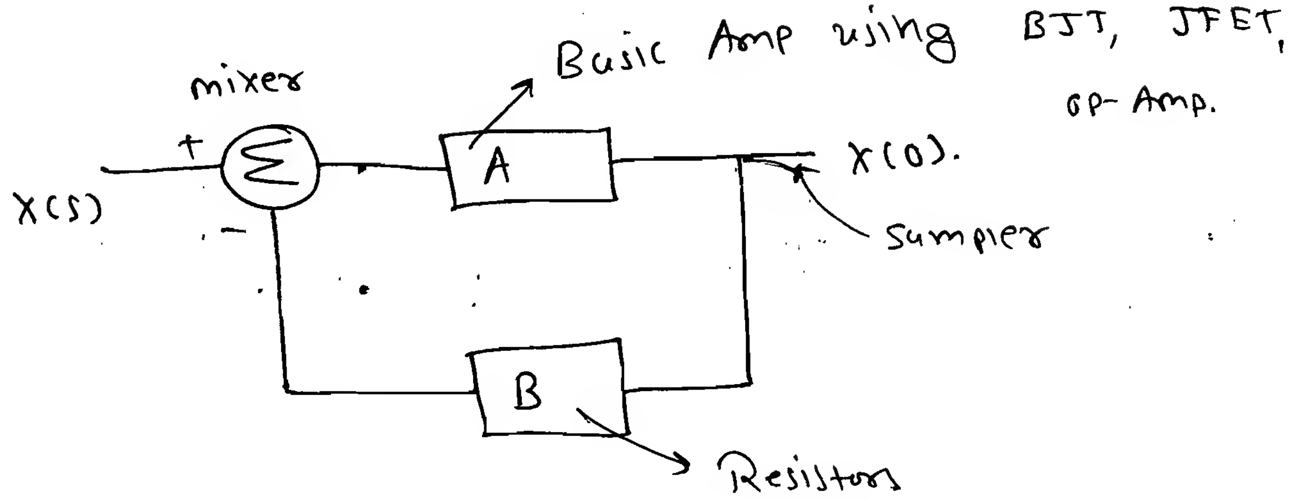
Sir: Kiran Kumar

Analog Circuits

→ PART - II

Best wishes

☆ Feedback Amplifiers:



⇒ Gain with feedback,

$$\frac{x(o)}{x(s)} = A_F = \frac{A}{1+A\beta}.$$

→ If loop gain $A\beta >> 1$.

⇓

$$A_F = \frac{A}{A\beta} = \frac{1}{\beta}.$$

⇒ β is designed with passive components which are predictable, stable and Accurate.

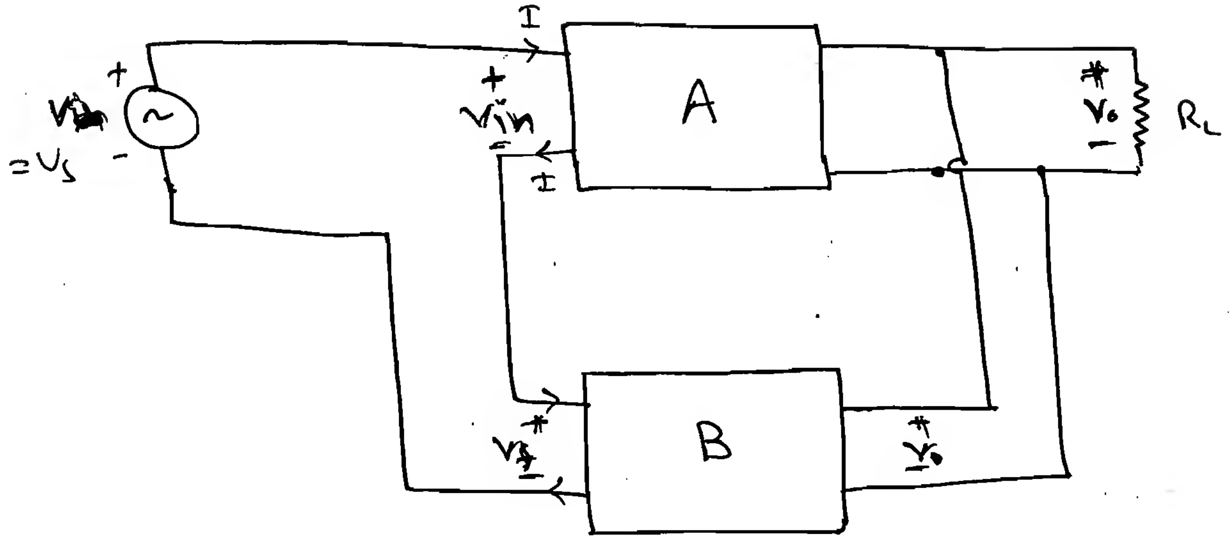
Hence, the Adv. of (-ve) feedback is to establish very accurate & stable gain.

⇒ Four types of Feedback:

Amp	Rin	Ro	Type of Feedback	
① Voltage	High	Low	ser. - shunt	(VCVS)
② Current	Low	High	shunt - ser	(CCCS)
③ Trans Conductance	High	High	ser - ser	(VCCS)
④ Trans Resistance.	Low	Low	Sh - Sh	(CCVS).

☆ Series - Shunt Feedback:

(VCVS)



$\therefore \quad V_s - V_{in} - V_f = 0$

$\therefore \quad V_{in} = V_s - V_f$ ← negative feedback.

1) $A = \dfrac{V_o}{V_{in}} = \dfrac{V_o}{V_s - V_f}$.

2) $\beta = \dfrac{V_f}{V_o}$.

Voltage Control Voltage Source.

high vin, Low V_o.

3) $A_F = \dfrac{A}{1+A\beta}$.

$A_F = \dfrac{V_o}{V_s}$.

$\therefore \quad \dfrac{V_o}{V_s} = \dfrac{A}{1+A\beta} = A_F$.

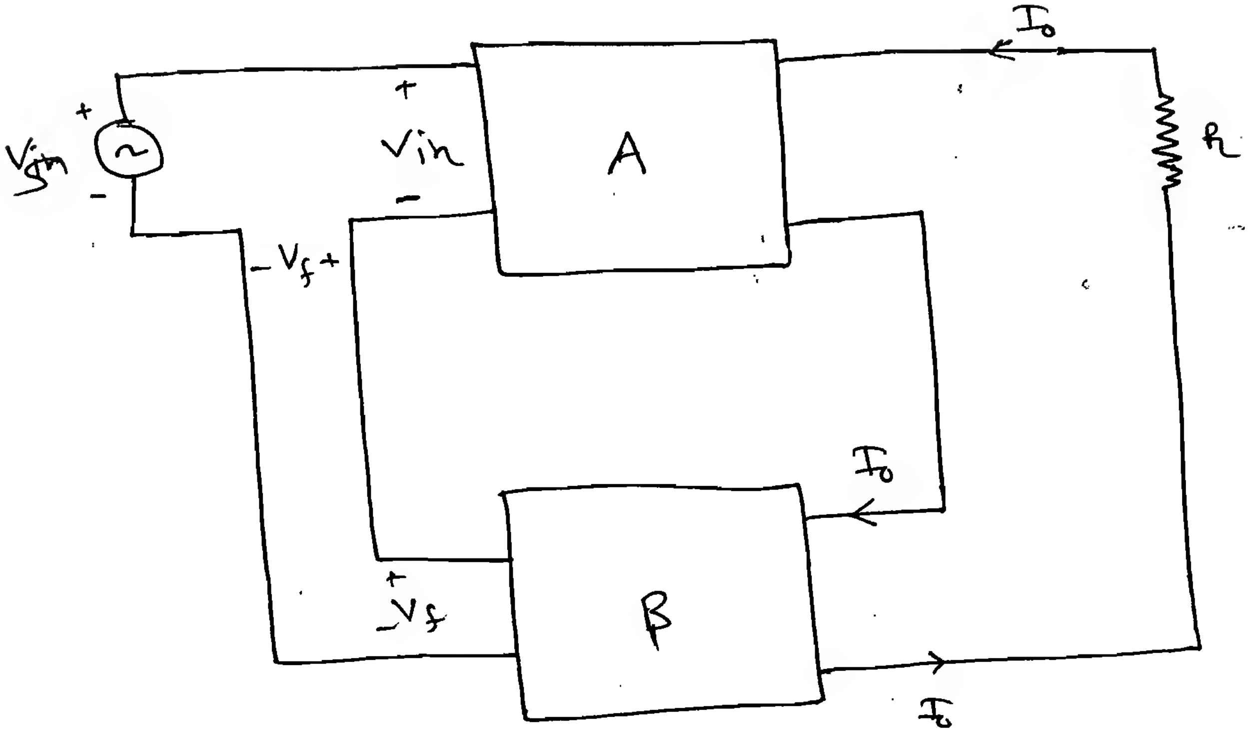
$\therefore \quad A = \dfrac{V_o}{V_s - V_f}$.

$\therefore \quad A = \dfrac{V_o}{V_s - \beta V_o}$.

$\therefore \quad AV_s - A\beta V_o = V_o$

* Series series Feedback:

(VCCS).



1) $A = \frac{I_o}{V_{in}}$.

$A = \frac{I_o}{V_s - V_f}$.

2) $\beta = \frac{V_f}{I_o}$.

3) $A_F = \frac{A}{1+A\beta}$.

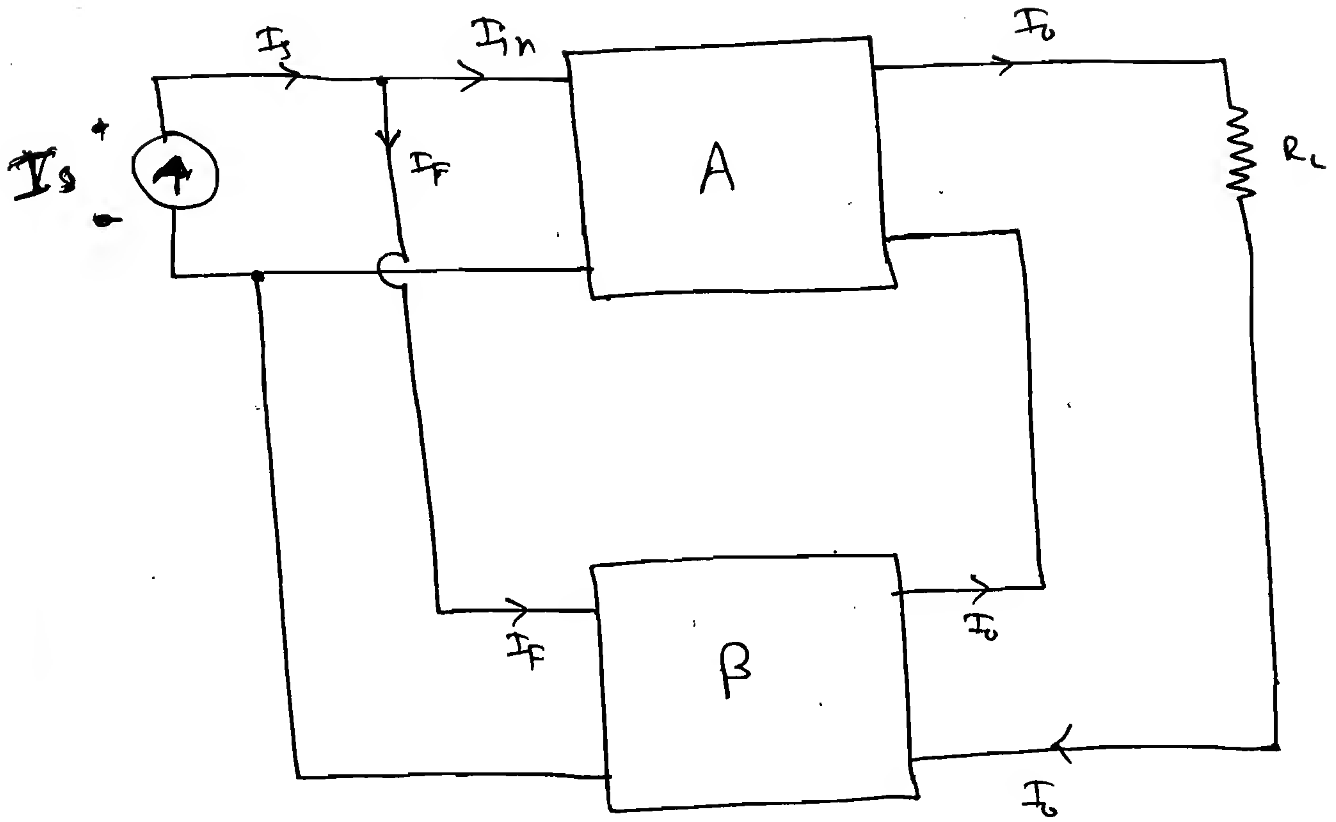
⇒ Voltage control current source.

Vin = high

V_o = high.

⇒ Transconductance. Amplifier.

☆ Shunt - series Feedback:



$\therefore \quad I_s = I_{in} + I_F.$

$\therefore \quad I_{in} = I_s - I_F.$ Negative feedback.

$\therefore$ 1) $A = \dfrac{I_o}{I_{in}} = \dfrac{I_o}{I_s - I_F}.$

$\therefore$ 2) $\beta = \dfrac{I_s}{I}.$ ⇒ Current control current source.

3) $A_F = \dfrac{A}{1+A\beta}.$

→ V_{in} = Low

V_o = High

→ current amplifier.

→ **Ex-1** Let, $I_s = 10\mu A$, $I_o = 100mA$.
$I_F = 6\mu A$, $A_f = ?$

$$\therefore A = \frac{I_o}{I_s - I_F} = \frac{100m}{10\mu - 6\mu A}$$

$$\therefore A = \frac{100m}{4\mu}$$

$$A = \frac{100 \times 10^{-3}}{4 \times 10^{-6}}$$

$$\therefore A = 25 \times 10^{3}$$

$$\therefore \boxed{A = 25000}$$

$$\therefore \beta = I_f / I_o$$

$$\therefore \beta = \frac{6 \times 10^{-6}}{100 \times 10^{-3}}$$

$$\therefore \beta = 60\mu$$

$$\therefore A_F = \frac{A}{1 + A\beta}$$

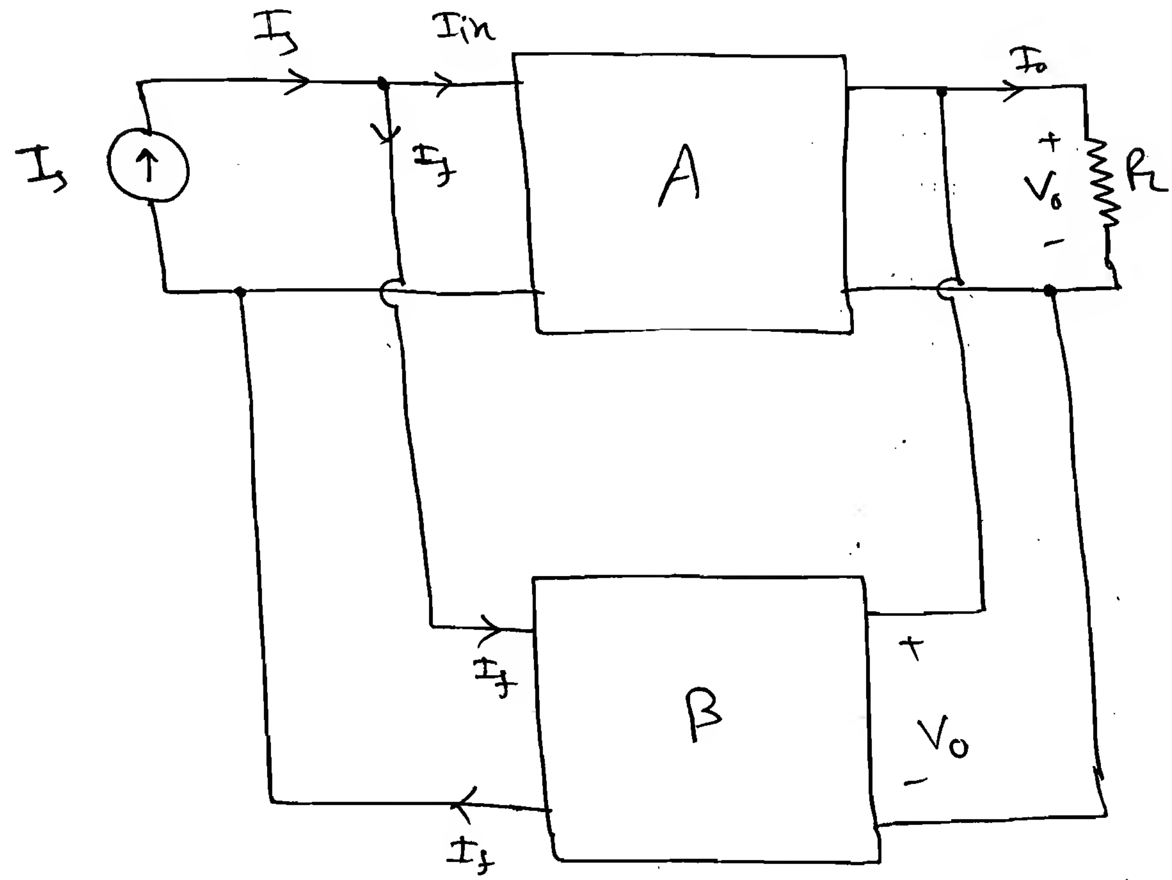
$$\therefore A_F = \frac{25000}{1 + (25000 \times 6 \times 10^{-5})}$$

$$\therefore \boxed{A_F = 10000}$$

☆ Trans Resistance Amplifier: (CCVS).

(Shunt - Shunt ~~Amm~~ feedback).

⇒



⇒ $I_{in} = I_s - I_f$.

∴ 1) $A = \dfrac{V_o}{I_{in}} = \dfrac{V_o}{I_s - I_f}$.

2) $\beta = I_f / V_o$.

3) $A_F = \dfrac{A}{1+A\beta}$.

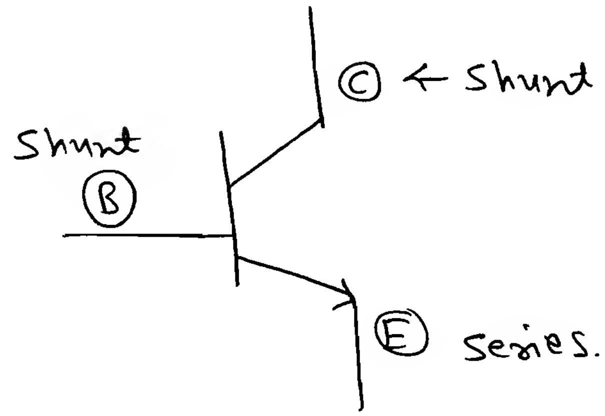
⇒ Current ~~[illegible]~~ Control Voltage ~~[illegible]~~ Source.

V_{in} = Low, V_o = Low.

★ Techniques for Identifying Feedback and Type of Ampliers.

Most Imp concept

(*)



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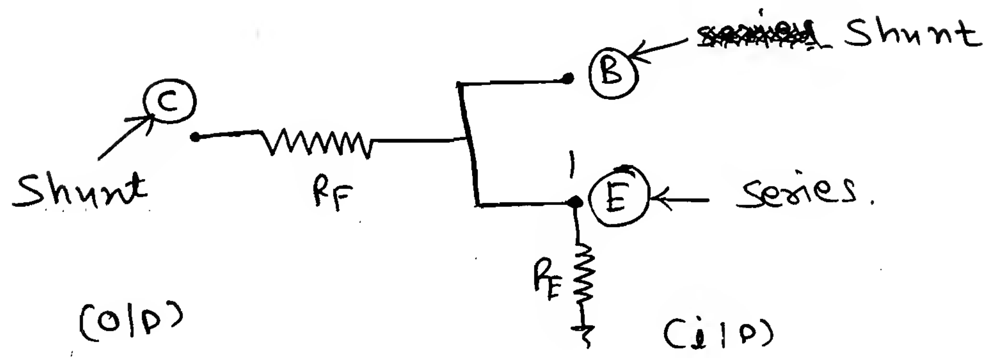

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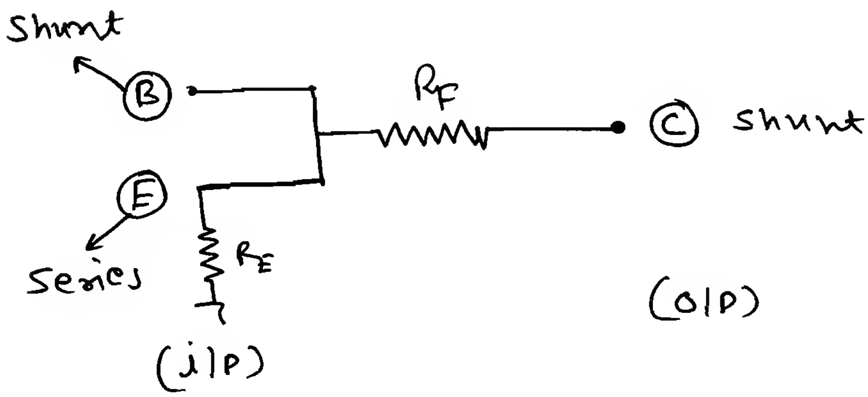

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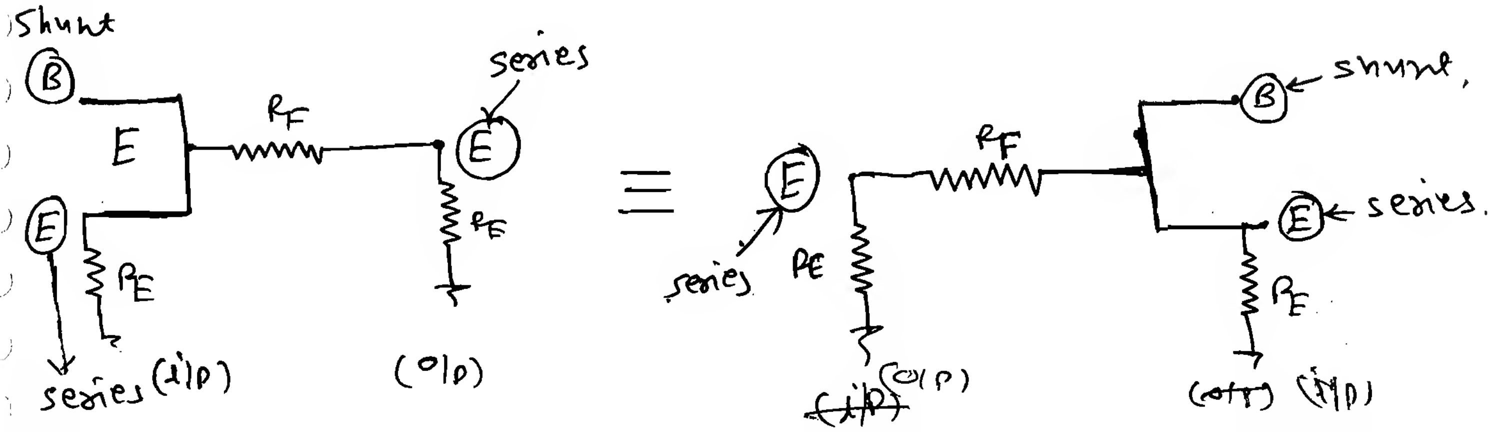


In words:

→ ① ~~Series~~ ~~Shunt~~.
If we take feedback from collector along with R_F in series then it is shunt (or) Voltage Sampling.

② If we take feedback from Emitter in series with R_F then it is called series (or) Current Sampling. Don't forget R_E. There should be R_E.

③ Now, If taken feedback from o/p if it is connected to Base of i/p then it is called Shunt mixing.

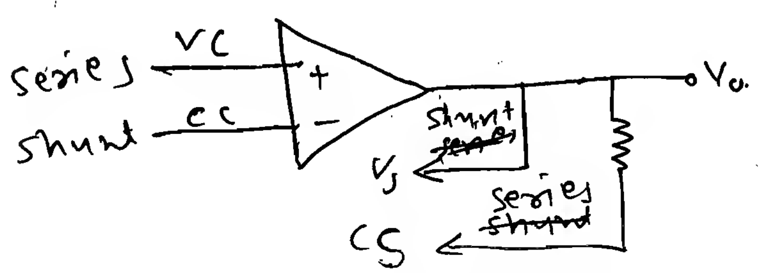
④ If taken feedback from o/p, if ~~it~~ is connected to Emitter of i/p then it is called series mixing.

* Now,

Series - series } → 1 stage, 3 stage.
Shunt - shunt

series - shunt } → 2 stage, 4 stage.
Shunt - series

* OPAMP



(1) Series Shunt Feedback:

→ Series → R_{in} = high → Vc
Shunt → R_o = Low → Vs
→ VCVS

VCVS → Voltage Series.

$\boxed{\text{2 Stage}}$

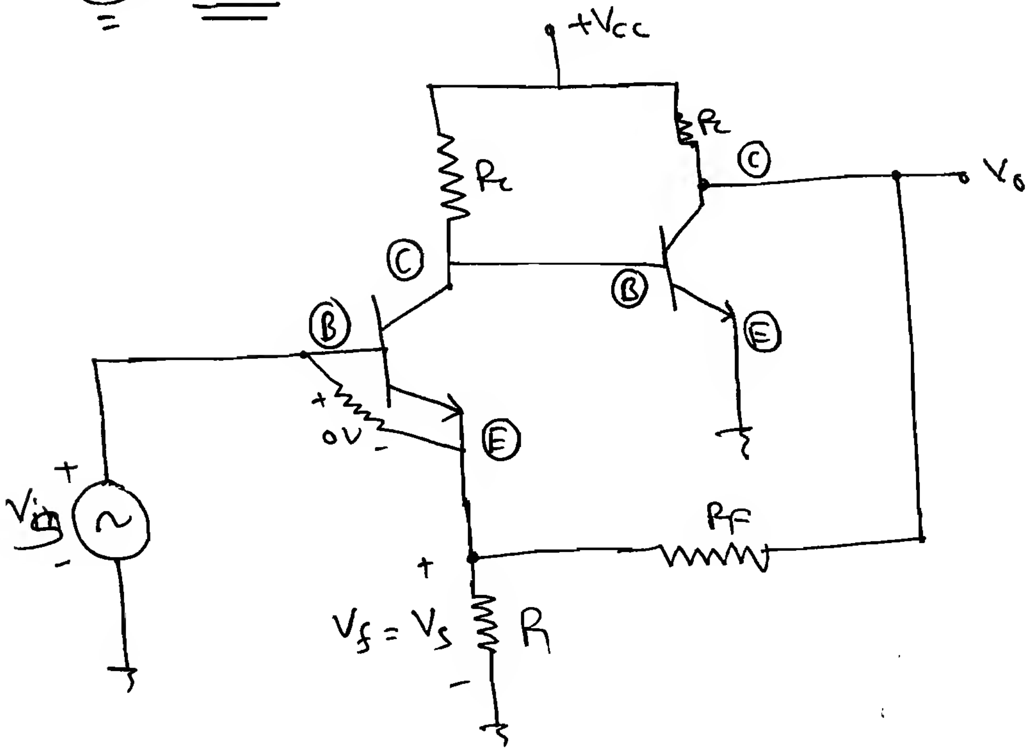
→ Voltage Amplifier.

$\therefore V_o = A_v V_s$.

$\therefore A_F = \frac{V_o}{V_s}$.

→ i/p = Voltage form
o/p = Voltage form.

(a) BJT



$$\Rightarrow V_s = \frac{R_1}{R_1+R_F} \cdot V_o.$$

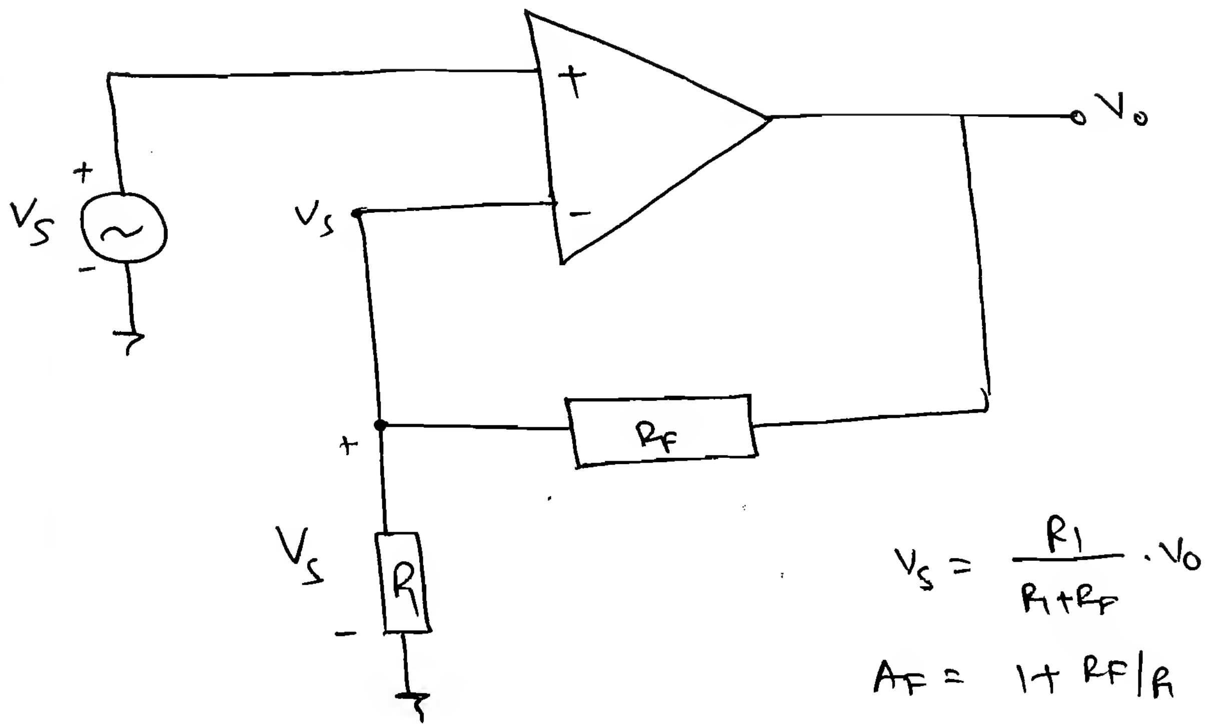
$$\Rightarrow A_F = \frac{V_o}{V_s} = \frac{R_1+R_F}{R_1}.$$

$$\therefore \quad A_F = \left(1 + \frac{R_F}{R_1}\right).$$

$$\therefore \quad \beta = \frac{1}{A_F}.$$

$$\therefore \quad \beta = \frac{R_1}{R_1 + R_F}.$$

② <u>op-Amp</u>:

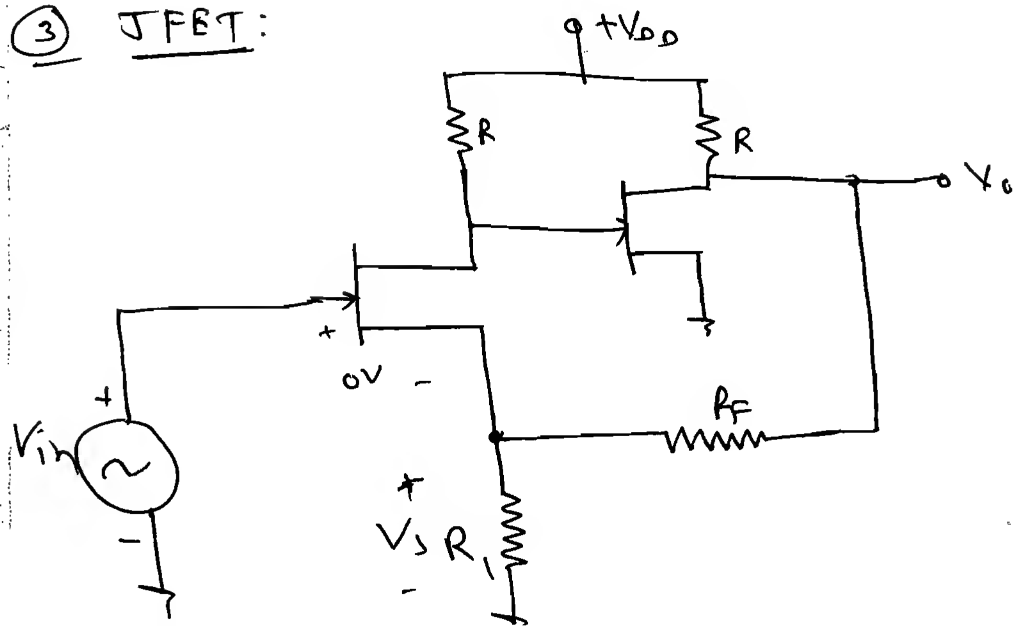


$$V_s = \frac{R_1}{R_1 + R_F} \cdot V_0$$

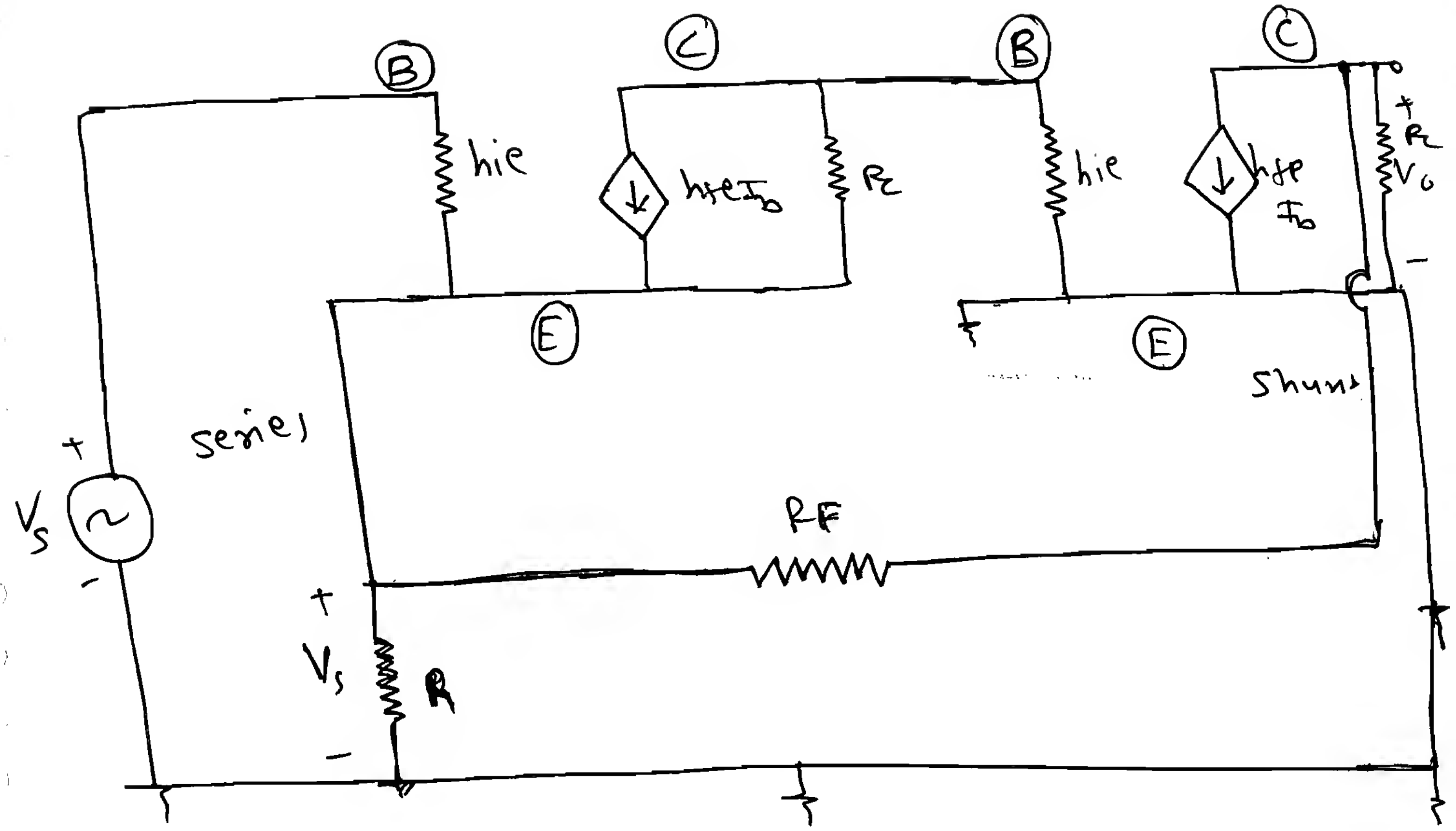
$$A_F = 1 + R_F / R_1$$

$$\beta = \frac{R_1}{R_1 + R_F}.$$

③ <u>JFET</u>:



* H-model



1. Series- Shunt feedback

2. $A_F = 1 + \frac{R_F}{R_1} = \frac{V_0}{V_s}$.

3. $\beta = 1/A_f$

$\Rightarrow \beta = \frac{R_1}{R_1 + R_F}$.

4. Voltage Amplifier.

5. Voltage control Voltage source Amplifier.

6. Voltage series amplifier.

7. $R_{inF} = R_{ino}(1 + A\beta)$.

8. $R_{oF} = \frac{R_{oo} \cancel{(1+A\beta)}}{1 + A\beta}$

(2) Shunt Shunt Feedback:

→ $R_{in} = \text{Low} \rightarrow CC$
$R_o = \text{Low} \rightarrow VS$ } → CCVS.

→ Shunt - Shunt

CC VS

$\boxed{\text{Voltage Shunt}}$

$\boxed{\text{1 stage}}$ or $\boxed{\text{3 stage}}$

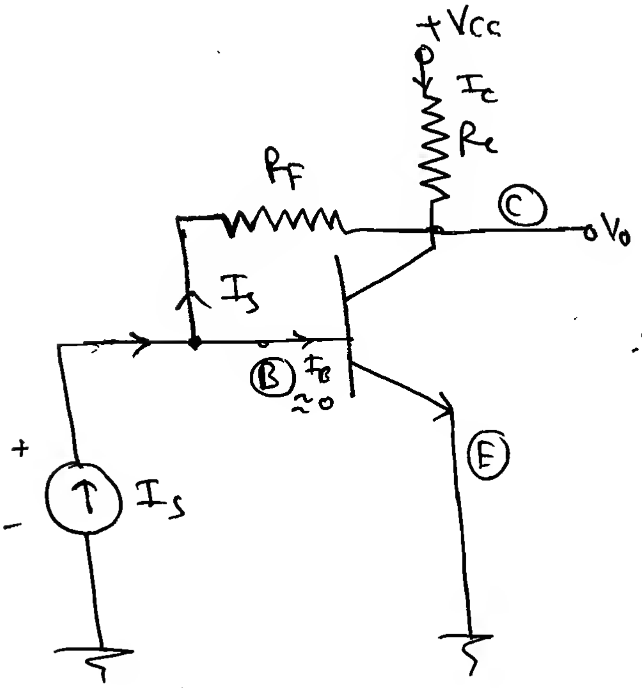
→ TransResistance Amplifier.

$$\therefore R_M = \frac{V_o}{I_s}$$

$$\therefore V_o = R_M \cdot I_s.$$

→ i/p = current form,
o/p = Voltage form.

(1) BJT:



$$I_c = I_o = -I_s.$$

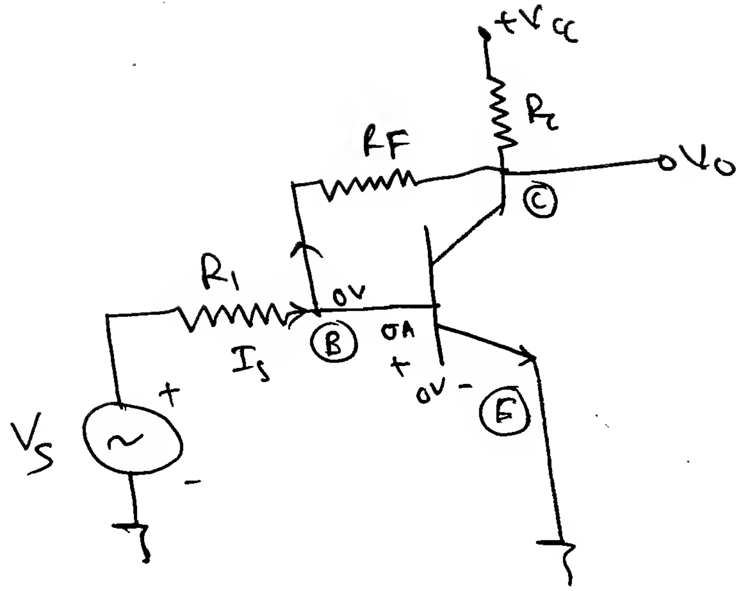
$$\therefore V_o = -I_s R_F$$

$$\therefore \boxed{\frac{V_o}{I_s} = -R_F}$$

$$\therefore A_F = \frac{V_o}{I_s} = -R_F$$

$$\therefore \boxed{\beta = 1/A_F = -1/R_F}$$

$\Rightarrow$



$$I_s = \frac{V_s - 0V}{R_1}.$$

$$\therefore V_s = I_s R_1.$$

KCL,
$$\frac{V_s - 0}{R_1} = \frac{0 - V_o}{R_F}.$$

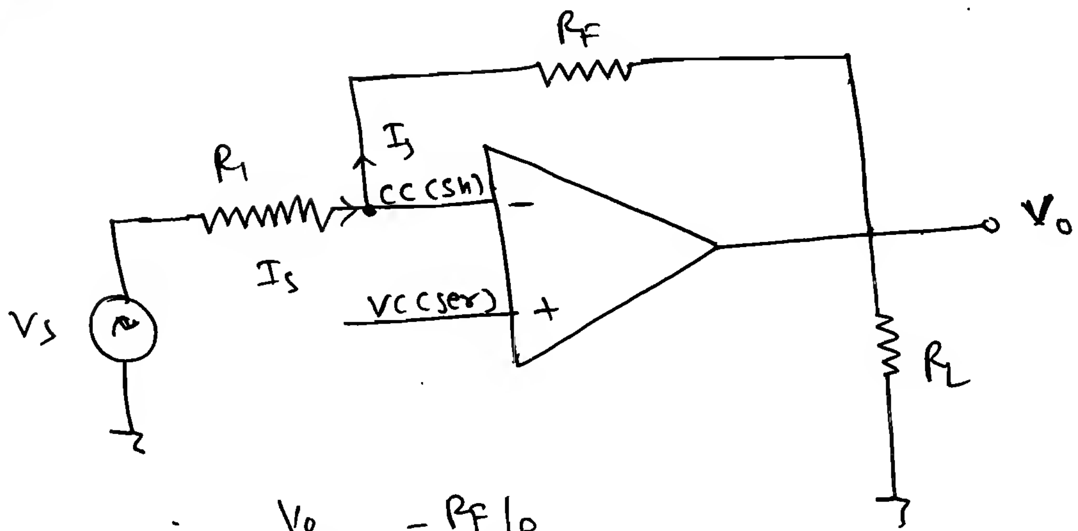
$$\therefore V_o = -\frac{R_F}{R_1} \cdot V_s.$$

$$\therefore V_o = -\frac{R_F}{\cancel{R_1}} \cdot \cancel{R_1} \cdot I_s$$

$$\therefore \boxed{\frac{V_o}{I_s} = A_F = -R_F} \;\therefore$$

$$\therefore \boxed{\beta = 1/A_F = -1/R_F}$$

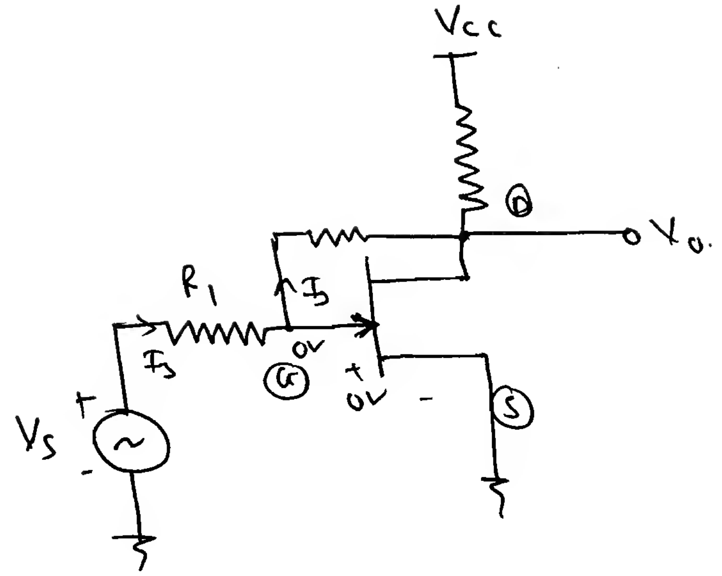
② <u>OPAMP</u> :



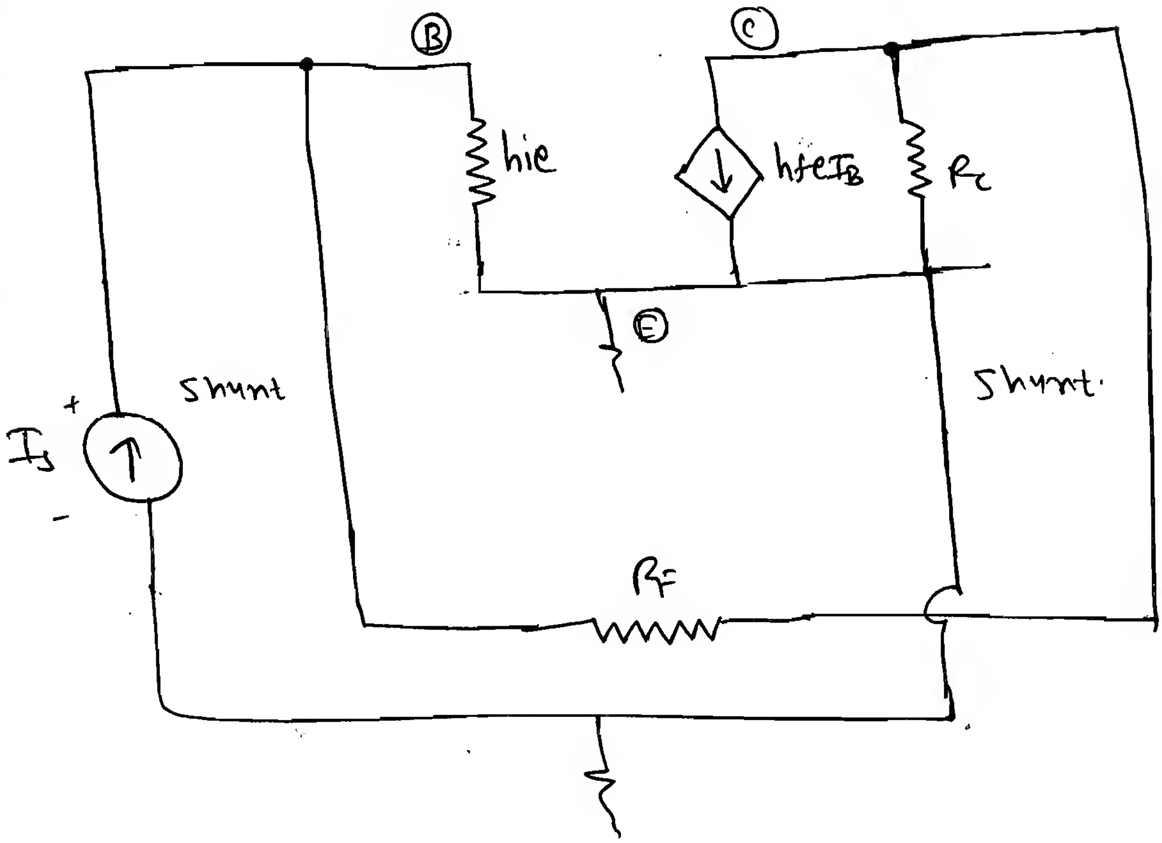
$$\therefore \frac{V_o}{V_s} = -R_F/R$$

$$\therefore \frac{V_o}{I_s} = -R_F = A_F \Rightarrow \beta = \frac{1}{A_F} = \frac{-1}{R_F}.$$

③ JFET:



* H-model:



① Shunt - Shunt

② CCVS

③ $A_F = -R_F$

④ $\beta = \frac{1}{A_F} = \frac{-1}{R_F}$

⑤ Voltage Shunt.

⑥ Transconductance.

⑦ $R_{inf} = \frac{R_{in}}{1+A\beta}$.

⑧ $R_{of} = \frac{R_o}{1+A\beta}$.

(3) Series - series Feedback:

→ R_{in} = high → VC
R_o = high → CS } → VCCS

Voltage Control current source.
(series)
VCCS
↓
current series.

Trans Conductance amplifier.

$\boxed{\text{(1) stage} \quad \text{(3) stage.}}$

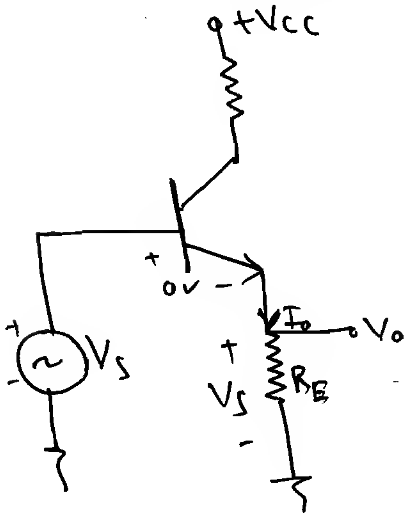
$\therefore \quad g_m = \dfrac{I_o}{V_s}$.

$\therefore \quad I_o = g_m V_s$.

i/p = Voltage form.
o/p = current form.

(1) BJT:

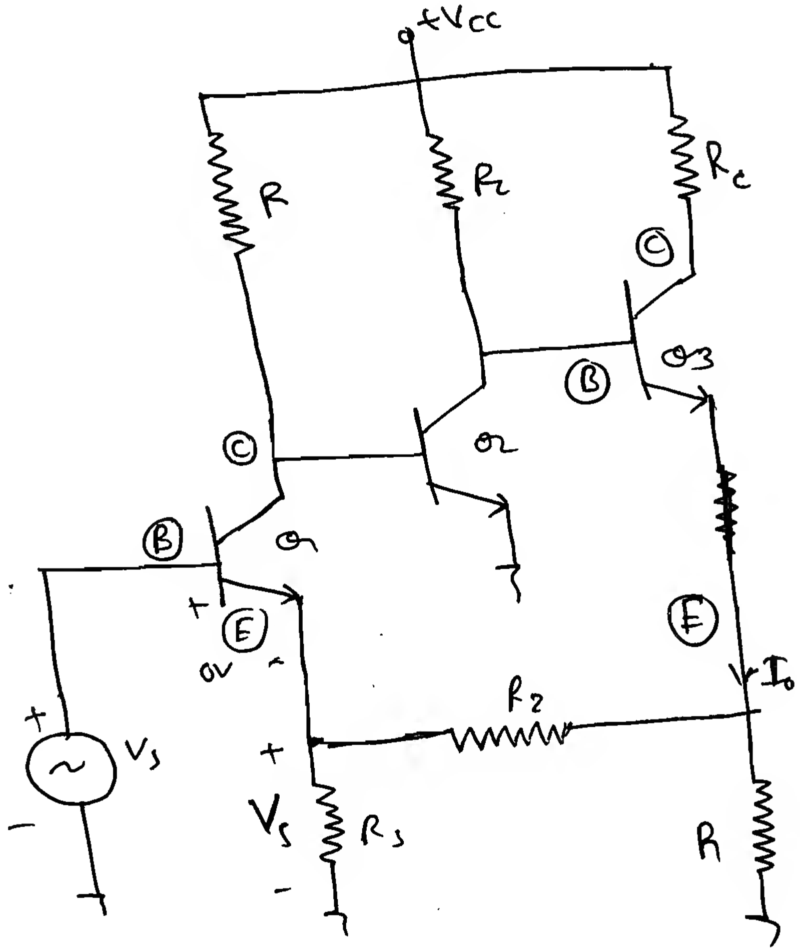
(1) single stage

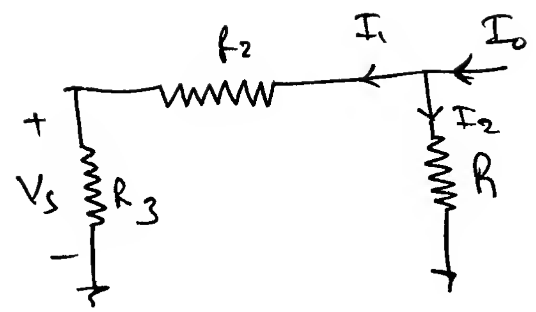


$\therefore V_s = I_o \cdot R_E$

$\therefore I_o = \dfrac{V_s}{R_E}$.

(2) 3-stage





$\therefore \quad V_s = I_1 \cdot R_3.$

Now, $\quad I_1 = \dfrac{R_1}{R+R_2+R_3} \cdot I_o.$

$$\therefore \quad V_s = \frac{R_1 \cdot R_3}{R_1+R_2+R_3} \cdot I_o.$$

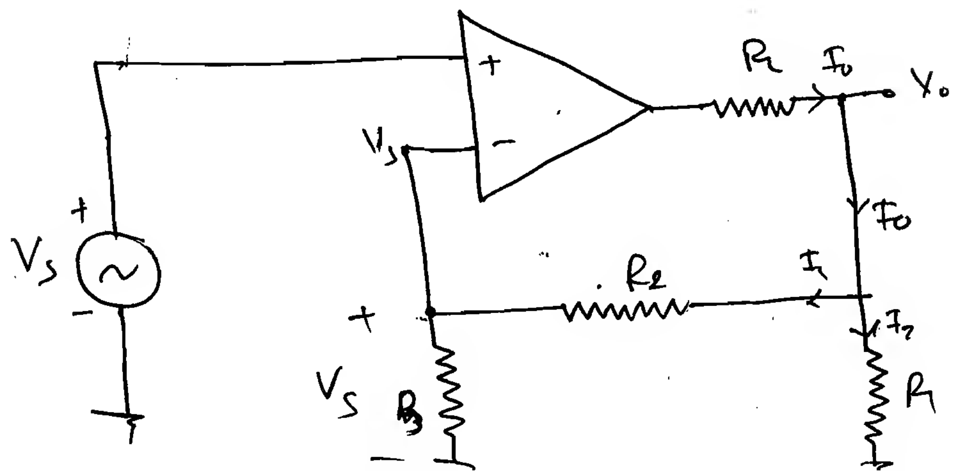
$$\therefore \quad g_m = \frac{I_o}{V_s} = \frac{R_1+R_2+R_3}{R_1 \cdot R_3}.$$

$$\therefore \quad \boxed{A_F = \frac{R_1+R_2+R_3}{R_1 \cdot R_3}}.$$

$$\beta = \frac{1}{A_F}.$$

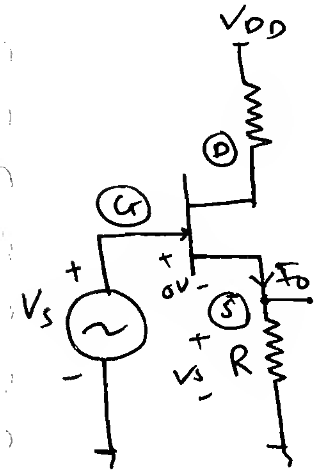
$$\therefore \quad \boxed{\beta = \frac{R_1 \cdot R_3}{R_1+R_2+R_3}}$$

② Op-Amp:



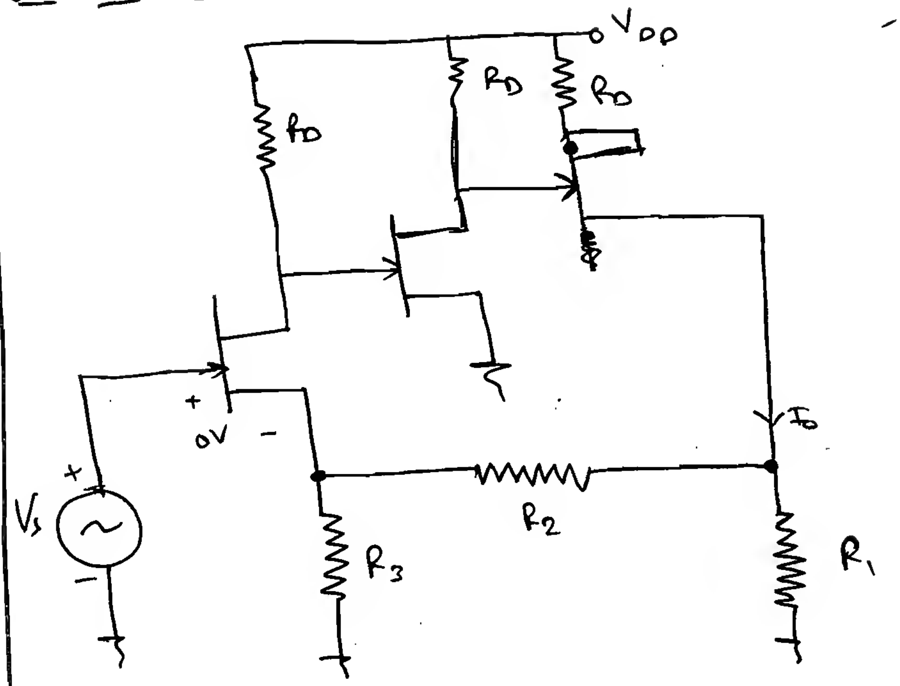
③ JFET:

(1) single stage:



$\therefore \boxed{I_o = \frac{V_s}{R}}$

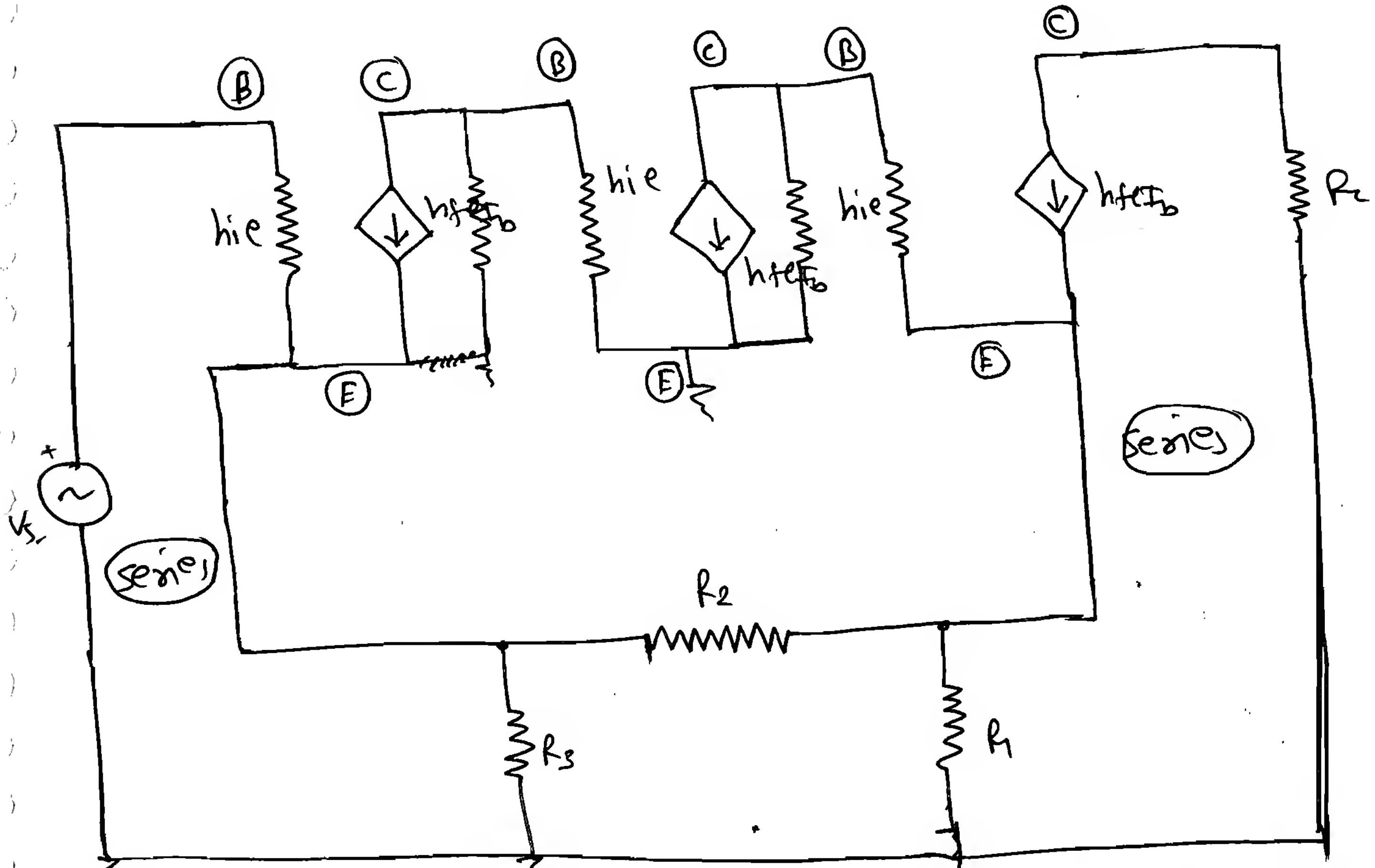
(2) 3- stage:



⑦ $R_{inF} = R_{in}(1+A\beta)$

⑧ $R_{oF} = R_o(1+A\beta)$.

H-model:



① series - series NB

④ $\beta = 1/A_F$

⑥ transresistance

② VCCS

③ $A_F = \frac{R_1 \cdot R_3}{R_1+R_2+R_3}$

⑤ current series ⑦ R

④ Shunt - series feedback:

→ R_{in} = Low → cc
R_o = high → cs } → CCCS.

current control current source.

2- stage

shunt - series
cc cs
↓
current shunt Amp.

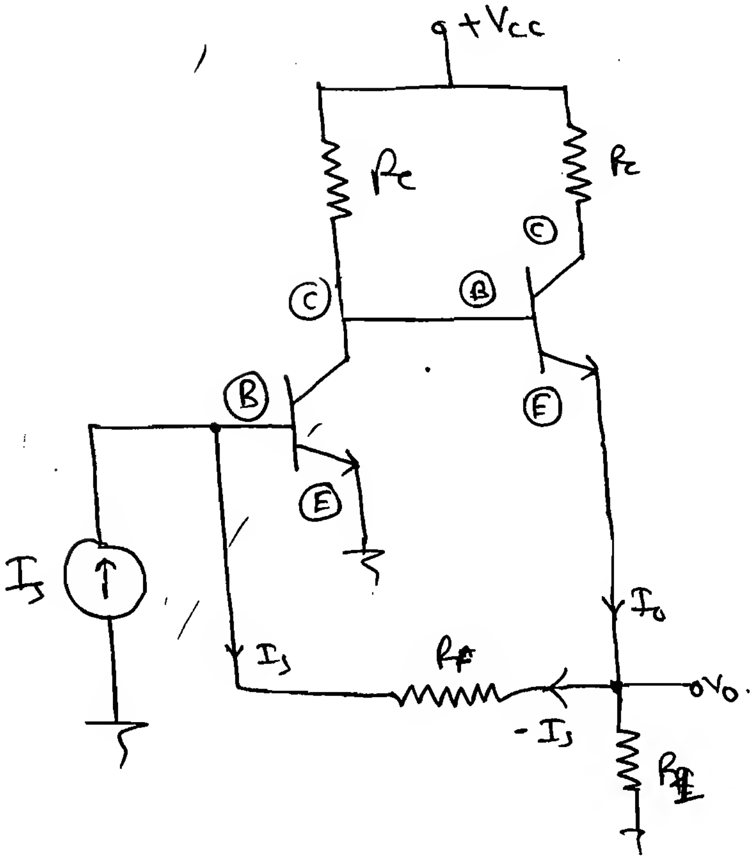
∴ Current Amplifier.

∴ $A_I = \frac{I_o}{I_s}$.

i/p : current form.
o/p : current form.

∴ $\boxed{I_o = A_I \cdot I_s}$

① BJT:

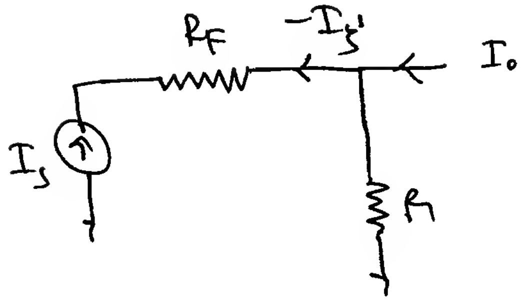


∴ $-I_s = \frac{R_1}{R_F + R_1} \cdot I_o$

∴ $\frac{I_o}{I_s} = A_F = -\left(1 + \frac{R_F}{R_1}\right)$

∴ $\boxed{A_F = -\left(1 + \frac{R_F}{R_1}\right)}$

$\boxed{\beta = \frac{-R_1}{R_1 + R_F}}$

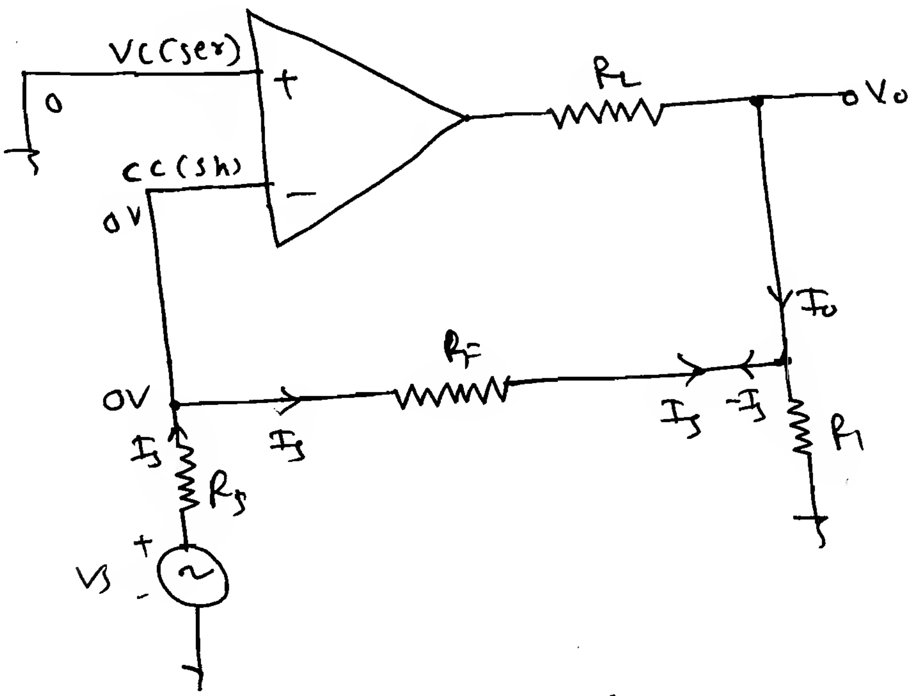


$\therefore \quad I_s = \dfrac{-R_1}{R_1+R_F} I_o$

$\therefore \quad \boxed{A_F = -\left(1+\dfrac{R_F}{R_1}\right) = \dfrac{I_o}{I_s}}$

$\therefore \quad \boxed{\beta = \dfrac{1}{A_F} = -\dfrac{R_1}{R_1+R_F}}$

② Op-Amp:



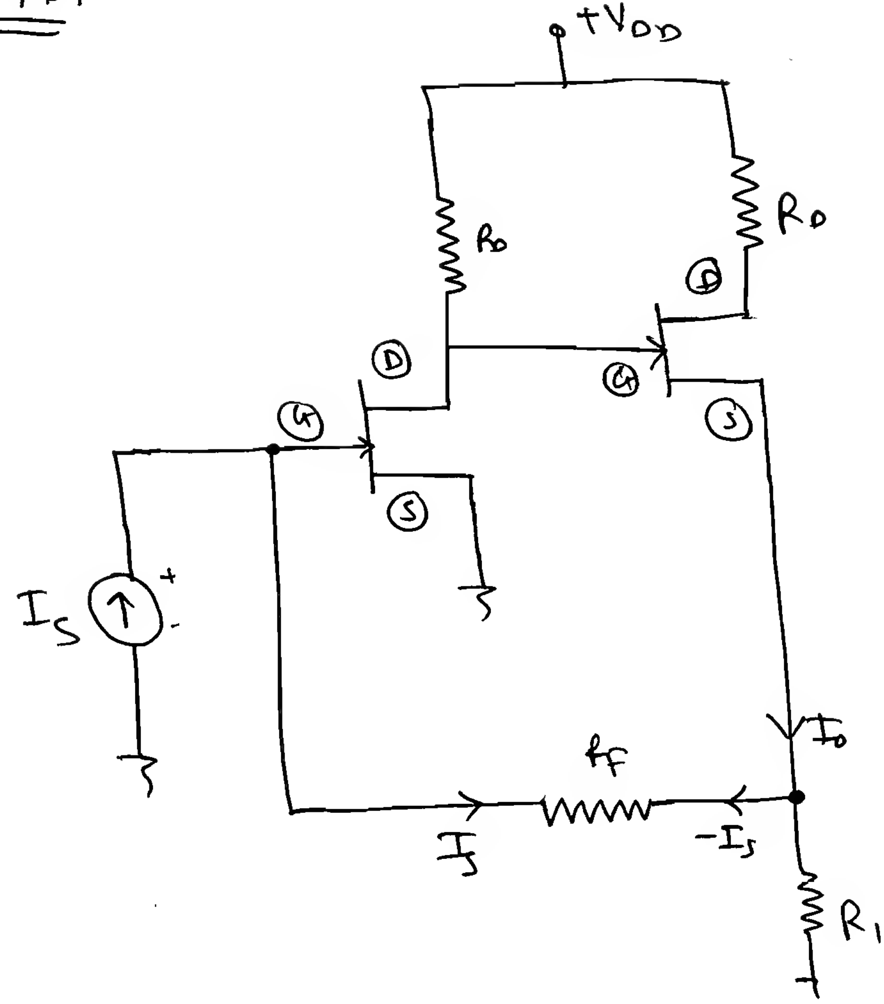
$\therefore \quad I_s = \dfrac{V_s - 0V}{R_s} = \dfrac{V_s}{R_s}$

$\therefore \quad -I_s = \dfrac{R_1}{R_1+R_F} \cdot I_o$

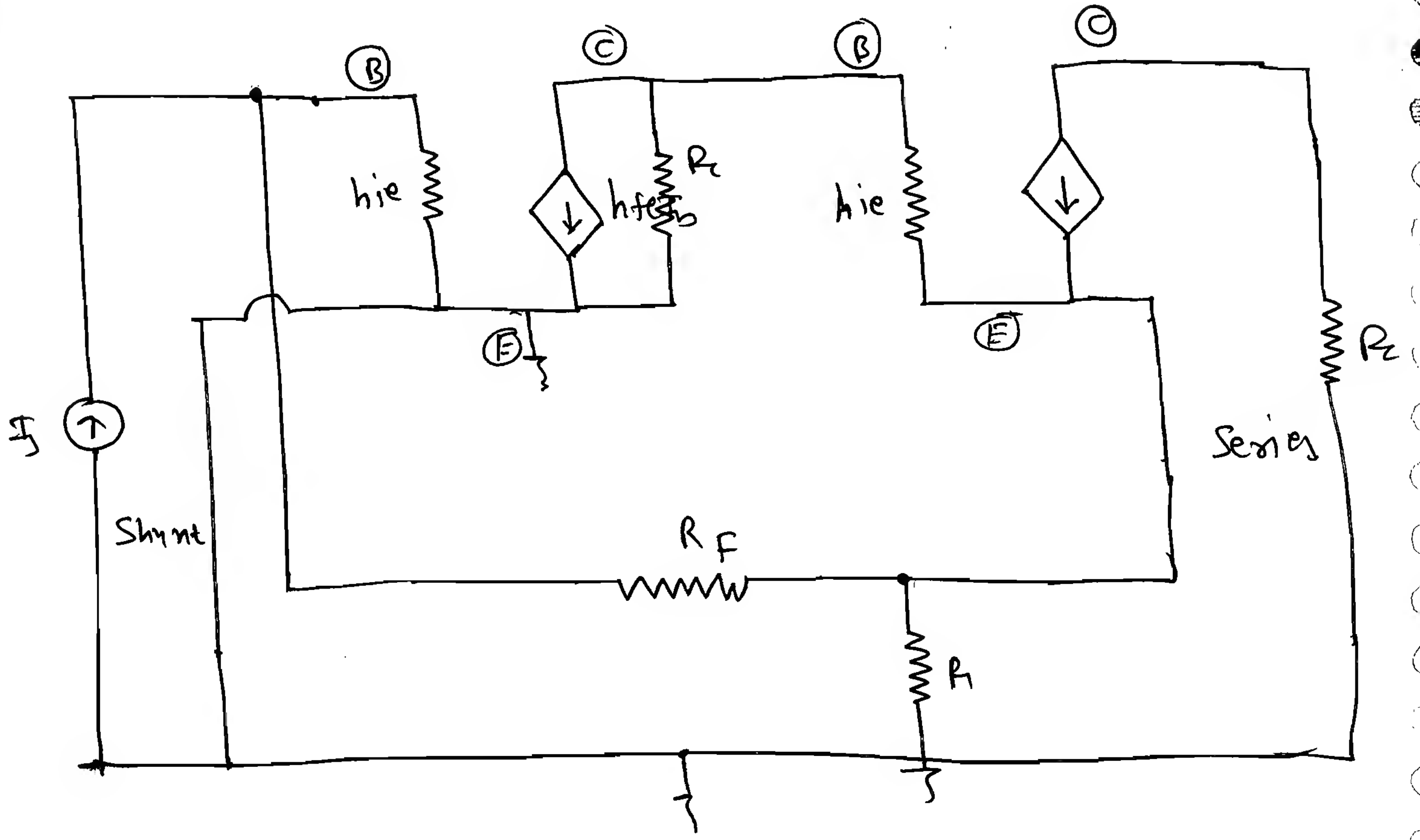
$\therefore \quad \dfrac{I_o}{I_s} = -\left(1+\dfrac{R_F}{R_1}\right)$

$\therefore \quad \boxed{A_F = -\left(1+\dfrac{R_F}{R_1}\right)} \Rightarrow \beta = -\dfrac{R_1}{R_1+R_F}$

③ JFET:



* H-Model:



① Shunt series A feedback.

② Current Control current source.

③ Gain $A_F = \frac{I_o}{I_s} = -\left(1 + \frac{R_F}{R_1}\right)$

④ $\beta = \frac{1}{A_F} = -\frac{R_1}{R_1 + R_F}$.

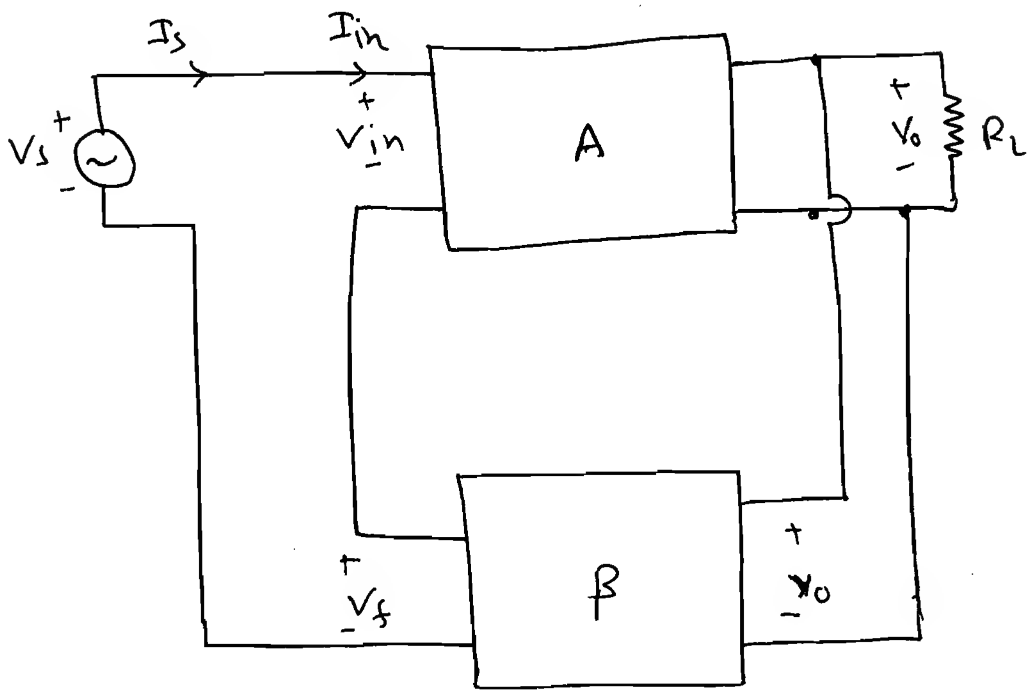
⑤ current shunt

⑥ Current Amplifier.

⑦ $R_{in_F} = \frac{R_{in}}{1 + A\beta}$.

⑧ $R_{oF} = R_o(1 + A\beta)$.

* Input and output Resistance of feedback Amp:-



→ $R_{in\,open} = \frac{V_{in}}{I_{in}}$.

$R_{in_F} = \frac{V_s}{I_s}$

$V_s = V_{in} + V_f.$

$\therefore R_{inF} = \dfrac{V_{in} + V_f}{I_s}$ But $V_f = \beta V_0.$

$\therefore R_{inF} = \dfrac{V_{in} + \beta V_0}{I_s}$, But $V_0 = A V_{in}.$

$\therefore R_{inF} = \dfrac{V_{in} + A\beta V_{in}}{I_{in}}$ $(\because I_{in} = I_s).$

$\therefore R_{inF} = \dfrac{V_{in}}{I_{in}} \cdot \times (1 + A\beta).$

$\therefore \boxed{R_{inF} = R_{in}(1 + A\beta)}$ (series).

similarly, $\boxed{R_{oF} = \dfrac{R_0}{(1+A\beta)}}$ (shunt).

* Amp.	R_{inF}	R_{oF}	
1) ser - sh Vc VS	$R_{in}(1+A\beta)$	$\dfrac{R_0}{1+A\beta}$	Voltage-series [h] F/B
2) sh - ser cc - CS	$\dfrac{R_{in}}{1+A\beta}$	$R_0(1+A\beta)$	current - Shunt [g] feed.
3) ser - ser Vc - CS	$R_{in}(1+A\beta)$	$R_0(1+A\beta)$	Current - series [Y] FB.
4) sh - sh cc - VS	$\dfrac{R_{in}}{1+A\beta}$	$\dfrac{R_0}{1+A\beta}$	Voltage-Shunt [Y] FB.

* $$A_F = \frac{A}{1+A\beta}.$$

$$\therefore \frac{dA_F}{dA} = \frac{(1+A\beta)(1) - A(\beta)}{(1+A\beta)^2}.$$

$$\therefore \frac{dA_F}{dA} = \frac{1}{(1+A\beta)^2}.$$

$$\therefore dA_F = \frac{dA}{(1+A\beta)^2}.$$

$$\therefore \frac{dA_F}{A_F} = \frac{dA}{A_F(1+A\beta)^2}.$$

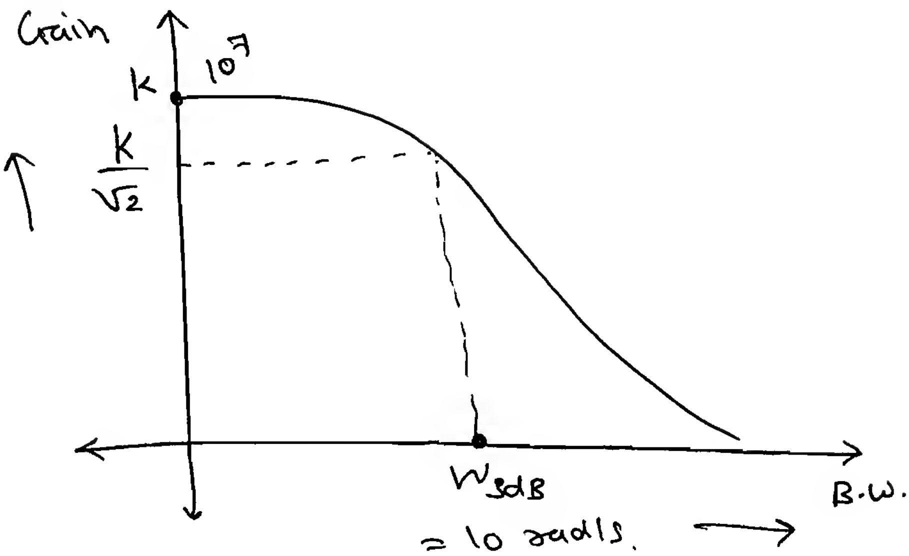
$$\therefore \frac{dA_F}{A_F} = \frac{dA}{\frac{A}{(1+\cancel{A\beta})^2} \times (1+A\beta)^{\cancel{2}}}$$

$$\therefore \boxed{\frac{dA_F}{A_F} = \frac{\frac{dA}{A}}{1+A\beta}}.$$

$$\therefore \boxed{\%\ \text{Change in } A_F = \frac{\%\ \text{Change in } A}{1+A\beta}}$$

→ "$1+A\beta$" is called desensitivity factor.

* BandWidth Extension:



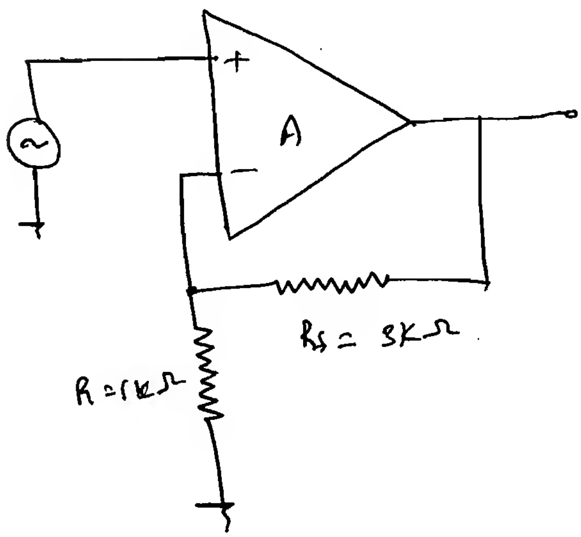
$\Rightarrow$ open loop gain, $A = \dfrac{k}{1 + \dfrac{s}{W_{3dB}}}$

where k is D.C. gain $= 10^6$ at $\boxed{f=0}$

$\therefore$ Gain x B.W. $= 10^6 \cdot 10 = 10^7$

$$\boxed{A = \text{Gain} = \frac{k}{1 + \frac{j\omega}{W_{3dB}}}}$$

* How to prove Gain x B.W. is Constant.



$\Rightarrow$ open loop gain

$A = \dfrac{k}{1 + \dfrac{s}{W_{3dB}}}$

$\therefore A = \dfrac{10^6}{1 + s/10}$.

& $\beta = \dfrac{R_1}{R_1 + R_f}$.

$\therefore \boxed{\beta = \frac{1}{4}}$

Now, Closed loop gain

$$A_F = \frac{A}{1+A\beta}$$

$$\therefore A_F = \frac{\frac{10^6}{1+\frac{s}{10}}}{1+\frac{\left(\frac{10^6}{1+\frac{s}{10}}\right)}{4}}$$

$$A_F = \frac{4\times10^6}{4\left(1+\frac{s}{10}\right)+\frac{10^6}{4}}$$

But at high freq. $\frac{s}{10} = \frac{j\omega}{10} = \frac{j2\pi f}{10} >> 1.$

$$\therefore A_F = \frac{4\times10^6}{\frac{4s}{10}+10^6}$$

$$= \frac{4}{1+\frac{4\left(\frac{s}{10}\right)}{10^6}}$$

$$\therefore \boxed{A_F = \frac{4}{1+\frac{s}{\left(10^7/4\right)}}}$$

So, New gain $K=4$

$$B.W. = \frac{10^7}{4}.$$

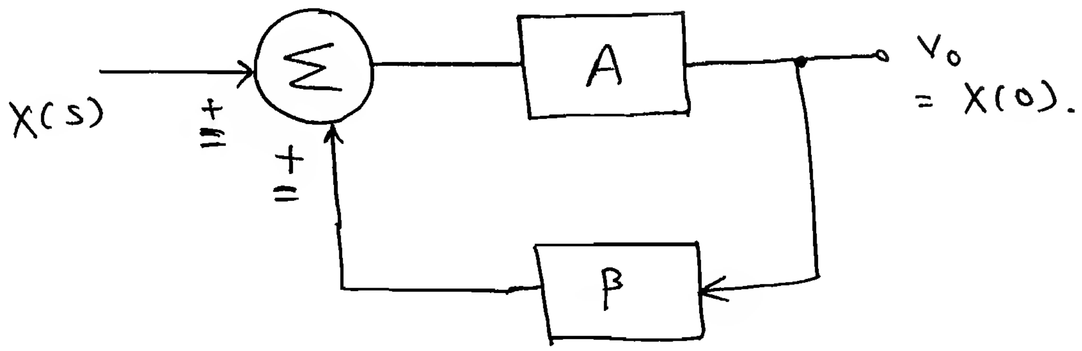
Before open loop gain, A	After Closed loop gain, A_f
Gain = 10^6	New Gain = 4.
B.W. = 10	B.W. = $10^7/4$.
Gain × B.W. = 10^7	Gain × B.W. = $10^7/4 \times 4 = 10^7$.

So, Gain, B.W. Products remains constant.

D: 25/7/2013

☆ Oscillators:

→ General configuration of +ve feedback,



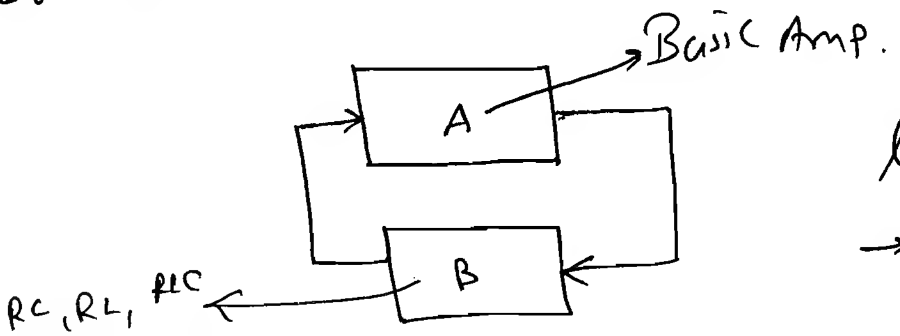
Gain with feedback.

$$\therefore \boxed{\frac{X(o)}{X(s)} = \frac{A}{1-A\beta}}$$

If $A\beta = 1$ then $A_f = \infty$.

→ Infinite gain means with no input we can aspect some O/P. Infact in an oscillator there is no input signal. oscillator works on noise (or) ckt transients.

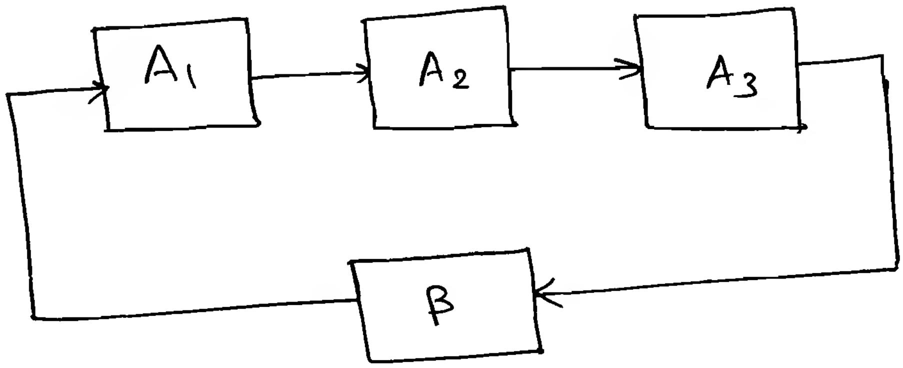
→ If no input then,



loop gain = 1.

→ $A\beta = 1$.

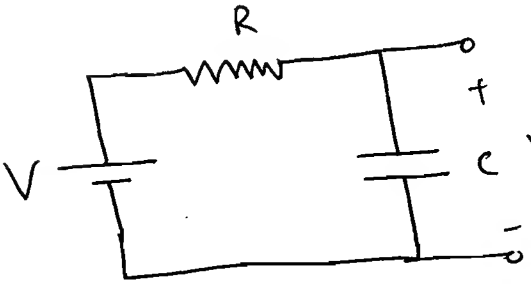
→



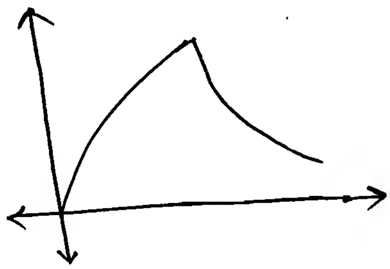
loop gain = 1.

$$\therefore \boxed{A_1 \cdot A_2 \cdot A_3 \cdot \beta = 1.}$$

*

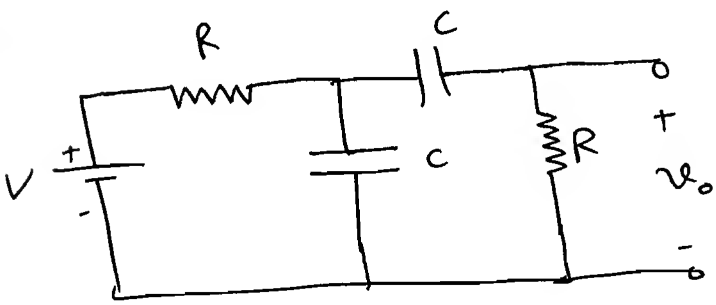


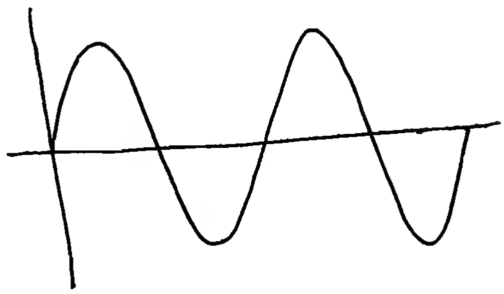
⇒



$$\frac{dy}{dx} + Py = Q.$$

*

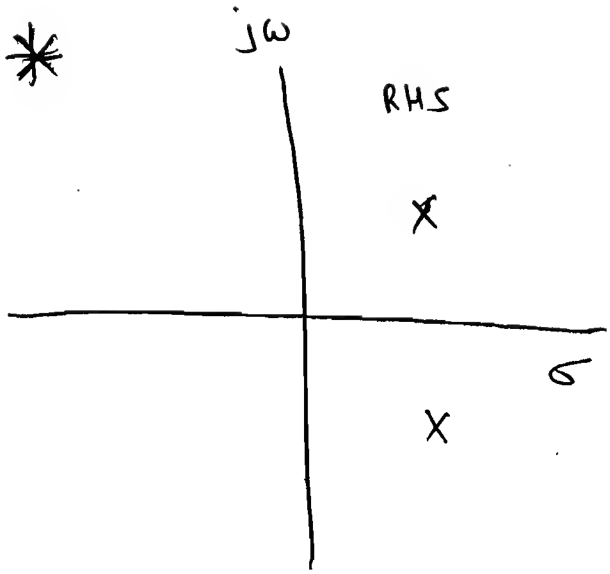




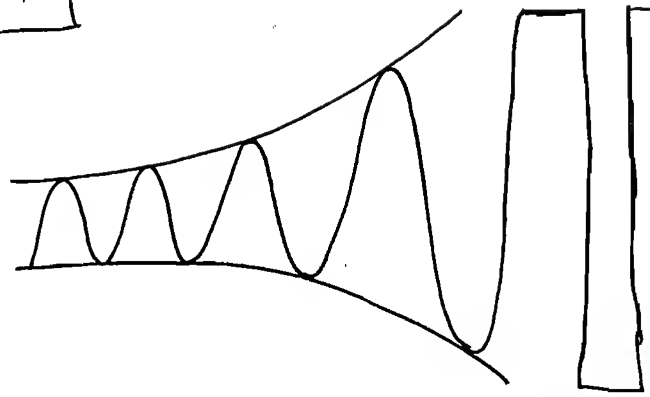
$$\frac{d^2y}{dx^2} + P\frac{dy}{dx} + Q = 0.$$

→ If we eliminate the middle term of above eqn then we can get sustain oscillation or perfect sine wave.

* $\boxed{A\beta > 1}$



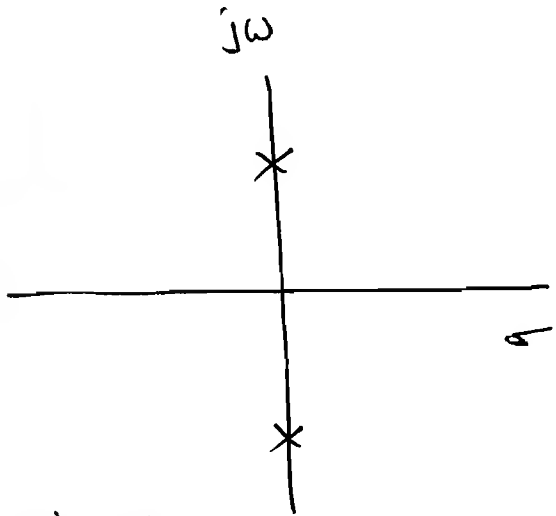
=>



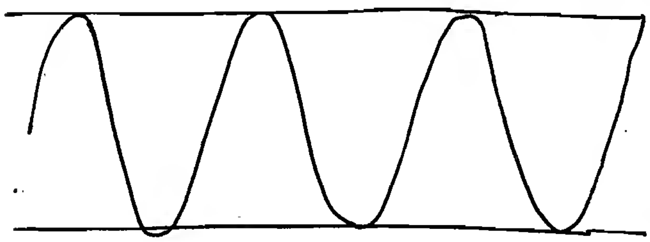
If we don't control the $A\beta > 1$ becom multi-vibrator (square wave)

→ Unstable

* $\boxed{A\beta = 1}$



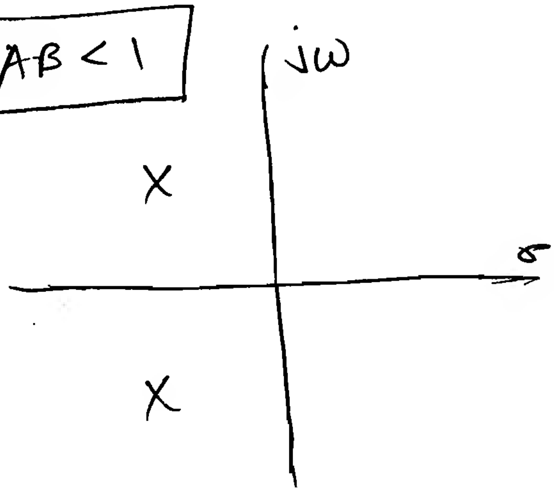
=>

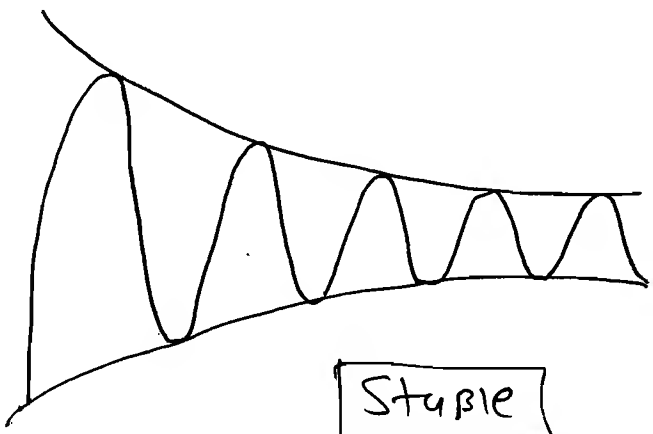


only at perticular freq. gain is unity.

Conditionaly Stable.

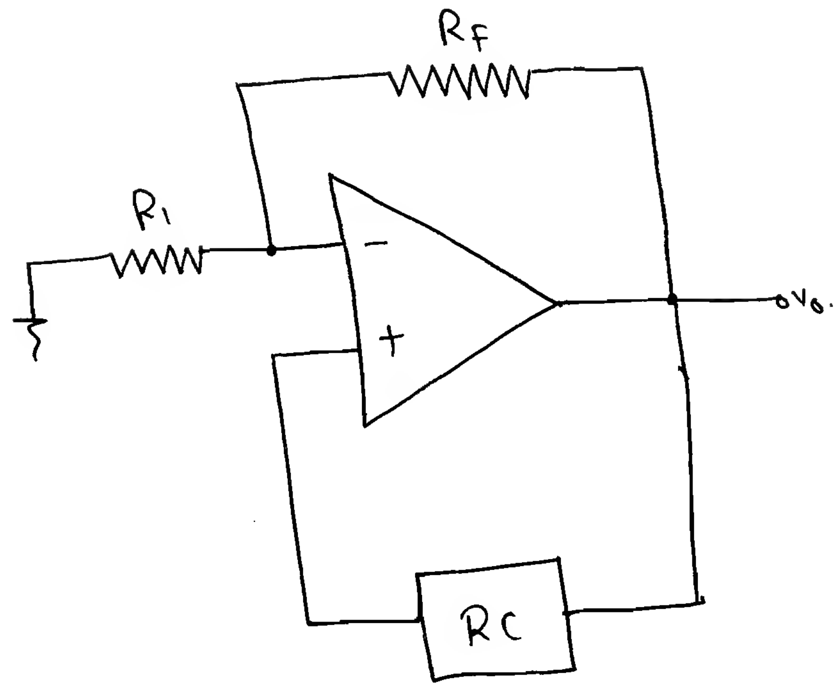
* $\boxed{A\beta < 1}$





$\boxed{\text{Stable}}$

*



→ We have to move ~~poles~~ Right hand side poles (Unstable) towards $j\omega$ axis so that the system become ~~un~~stable.

→ Now, If we decrease the R_F poles goes to left side of the plane and if we increase the R_F poles goes to Right hand side of the plane.

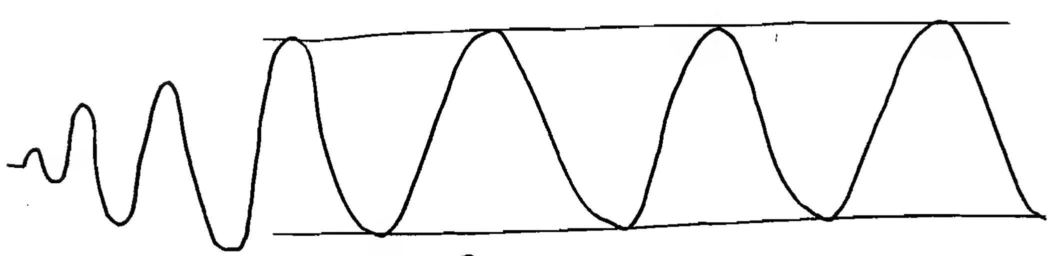
→ Let. $s = \sigma + j\omega$.

→ At the closed of power supply,

Transient response

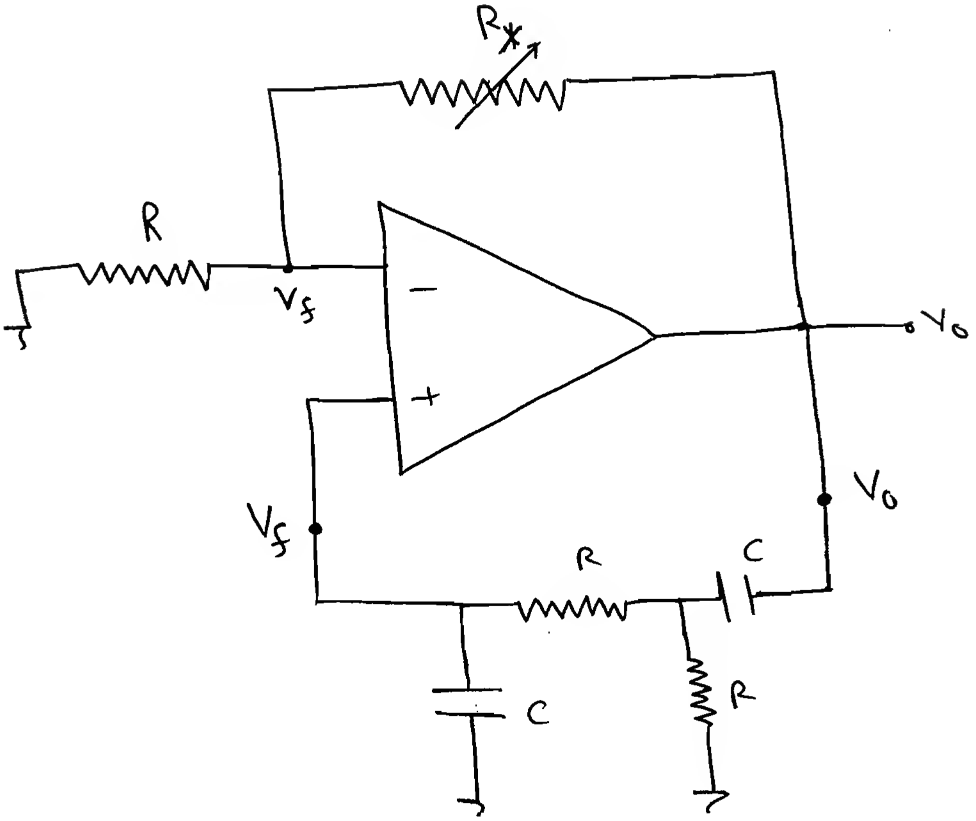
$$v(t) = e^{\sigma_o t} \left[e^{j\omega_o t} + e^{-j\omega_o t} \right].$$

$$v(t) = 2e^{\sigma_o t} \cdot \cos\omega_o t$$



* Find the Value of Resistor R_x for sustained oscillations. Also find the freq. of this oscillations.

→



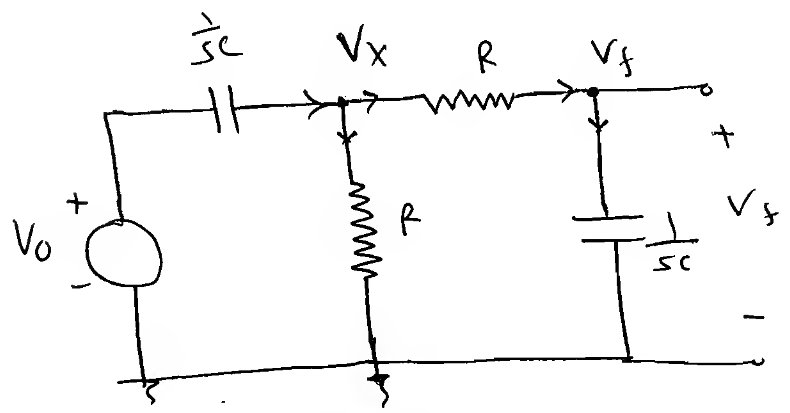
loop gain = 1.

$A\beta = 1.$

① $A_F = \frac{V_o}{V_f}.$ ② $\beta = \frac{1}{A_F} = \frac{V_f}{V_o}.$

→ Now, $A_F = \left(1 + \frac{R_x}{R}\right)$

∴



KCL,

$$\therefore \frac{V_o - V_x}{1/sC} = \frac{V_x}{R} + \frac{V_x - V_f}{R}.$$

$$\therefore RsC(V_o - V_x) = 2V_x - V_f.$$

$$\therefore RsC\,V_o = (2 + RsC)V_x - V_f.$$

$$\rightarrow \frac{V_x - V_f}{R} = \frac{V_f}{1/sC}.$$

$$\therefore V_x - V_f = RsC\,V_f.$$

$$V_x = (1 + RsC)V_f.$$

$$\therefore RsC\,V_o = (2 + RsC)(1 + RsC)V_f - V_f.$$

$$RsC\,V_o = (2 + 3RsC + R^2 s^2 C^2 - 1)V_f.$$

$$\therefore RsC\,V_o = (1 + 3RsC + R^2 C^2 s^2)V_f.$$

$$\therefore \beta = \frac{V_f}{V_o} = \frac{1}{3 + RCs + \frac{1}{RCs}}$$

$$s = j\omega$$

$$\therefore \beta = \frac{1}{3 + j\left(\omega RC - \frac{1}{\omega RC}\right)}.$$

Now, $A\beta = 1$

$$A = \frac{1}{\beta}.$$

$$\therefore \left(1 + \frac{R_x}{R}\right) = 3 + j\left(\omega RC - \frac{1}{\omega RC}\right).$$

Compare real part,

$$\therefore 1 + \frac{R_x}{R} = 3$$

$$\therefore \boxed{R_x = 2R}$$

Compare img. part.

$$\omega RC - \frac{1}{\omega RC} = 0.$$

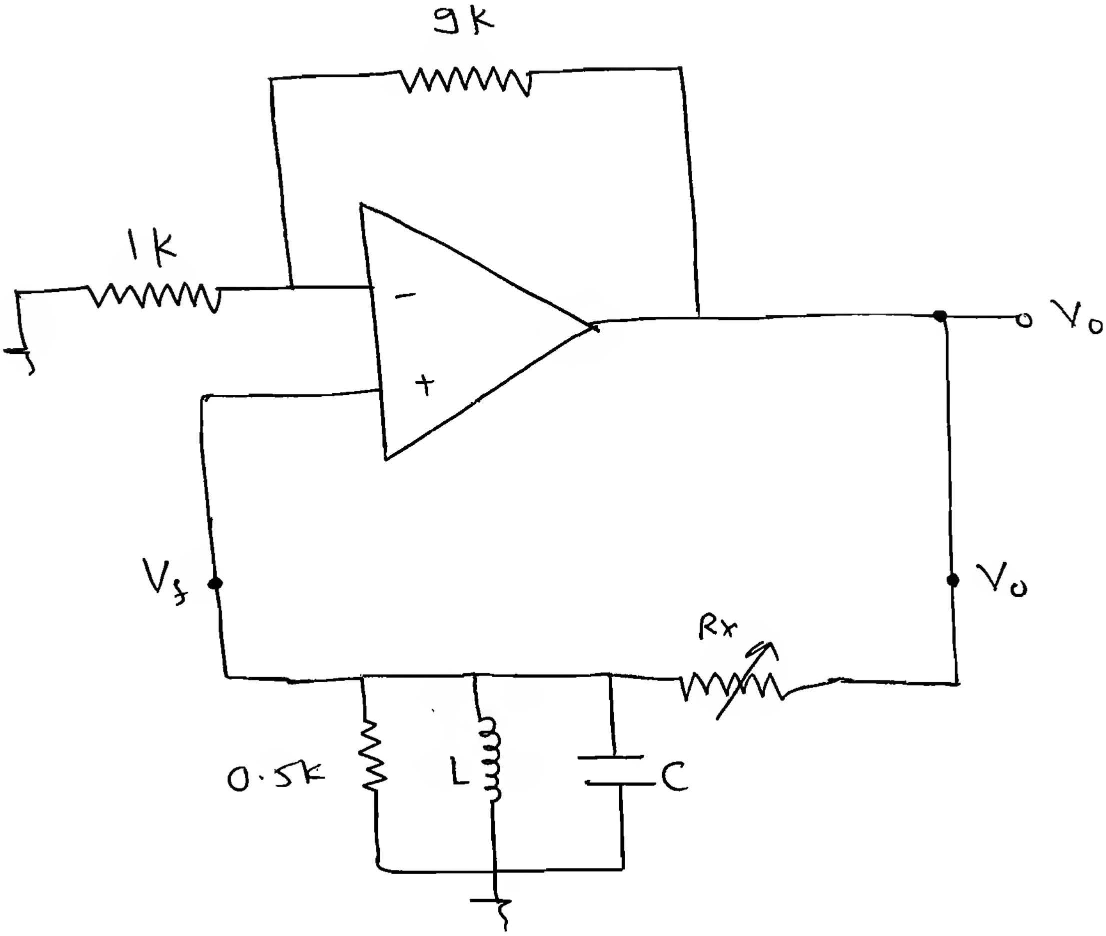
$$\omega^2 = \frac{1}{(RC)^2}.$$

$$\therefore \omega = \frac{1}{RC}.$$

$\therefore \boxed{R_x = 2R}$; $\boxed{f = \frac{1}{2\pi RC}}$

* Find the value of R_x of sustain oscillation. Also find the freq. of this oscillators.

→



⇒ loop gain = 1

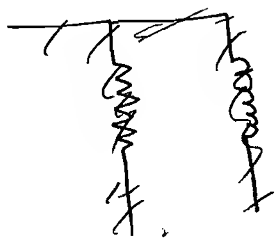
$A\beta = 1.$

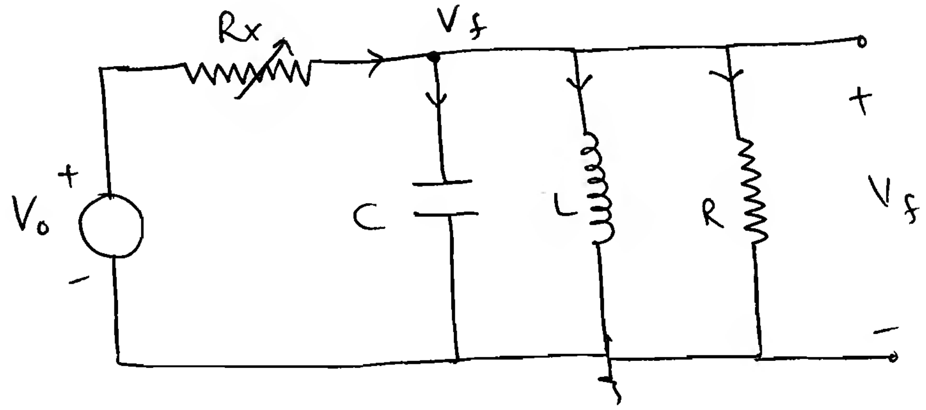
① $A_F = \frac{V_o}{V_f}$ ② $\beta = \frac{V_f}{V_o} = 1/A.$

$\therefore \rightarrow \quad A_F = \left(1 + \frac{9K}{1K}\right) = 10$

$\therefore \boxed{A_F = 10}$

Now.





→ KCL,

$$\frac{V_o - V_f}{R_x} = V_f\left(sC + \frac{1}{LC} + \frac{1}{R}\right).$$

$$\therefore \frac{V_o}{R_x} = V_f\left(sC + \frac{1}{LC} + \frac{1}{R} + \frac{1}{R_x}\right).$$

$$\therefore \beta = \frac{V_f}{V_o} = \frac{\cancel{R_x}}{R_x\left(sC + \frac{1}{LC} + \frac{1}{R} + \frac{1}{R_x}\right)}.$$

Now,

$$A\beta = 1$$

$$A = \frac{1}{\beta}.$$

$$\therefore 10 = \frac{\left(sC + \frac{1}{LC} + \frac{1}{R} + \frac{1}{R_x}\right)R_x}{\cancel{R_x}}.$$

$$\therefore s = j\omega$$

$$\therefore \frac{10}{R_x} = j\left(\omega C - \frac{1}{\omega L}\right) + \frac{1}{R} + \frac{1}{R_x}.$$

equate real part.

$$\therefore \frac{10}{R_x} = \frac{1}{R} + \frac{1}{R_x}.$$

$$\therefore \frac{9}{R_x} = \frac{1}{R}.$$

$$\therefore R_x = 9R.$$

$$\therefore R_x = 9\,(0.5)\,k$$

$\therefore \boxed{R_x = 4.5 K\Omega}$

$\therefore$ equate Imaginary part.

$$\therefore \omega C - \frac{1}{\omega L} = 0.$$

$$\omega^2 = \frac{1}{LC}.$$

$$\therefore \omega = \frac{1}{\sqrt{LC}}.$$

$$\therefore \boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

* Barkausen Criteria:

$$\boxed{A\beta = 1\angle 0^\circ \text{ or } 360^\circ}$$

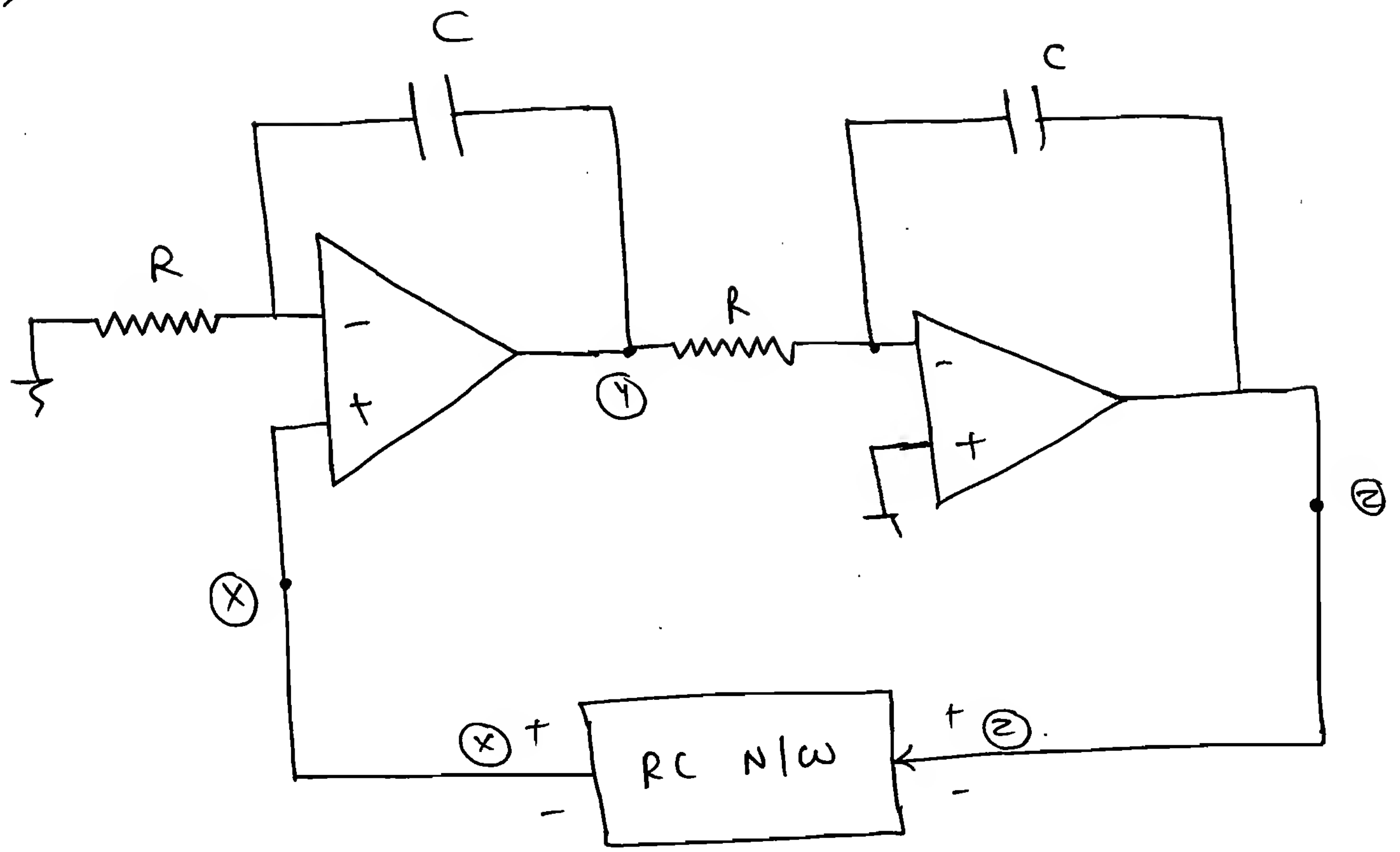
① Magnitude of loop gain is unity.

② phase angle of loop gain is 0° or 360°.

* De

* Design an RC N/w for Sustain oscillator at a freq. $\omega = \frac{1}{RC}$.

⇒



→ loop gain $A\beta = 1$.

$$\therefore \frac{Y}{X} \cdot \frac{Z}{Y} \cdot \frac{X}{Z} = 1.$$

$$\therefore \frac{Y}{X} = \left(1 + \frac{1}{sCR}\right).$$

$$\therefore \frac{Z}{Y} = \left(-\frac{1}{sCR}\right).$$

$$\text{So,} \quad \left(1+\frac{1}{sCR}\right)\left(-\frac{1}{sCR}\right)\cdot\left(\frac{X}{Z}\right) = 1.$$

$$\therefore -\frac{(sCR+1)}{(sCR)^2} \cdot \frac{X}{Z} = 1.$$

$$\therefore \frac{X}{Z} = -\frac{(sCR)^2}{1+sCR}.$$

$$\therefore \quad \frac{X}{Z} = -\frac{(SCR)^2}{1+SCR}.$$

Now, $\quad s = j\omega.$

$$\frac{X}{Z} = \frac{\omega^2 R^2 C^2}{1+SCR}.$$

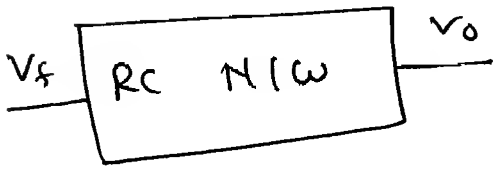
Put $\omega = \frac{1}{RC}$ in numerator.

$$\therefore \quad \frac{X}{Z} = \frac{1}{1+SCR}.$$

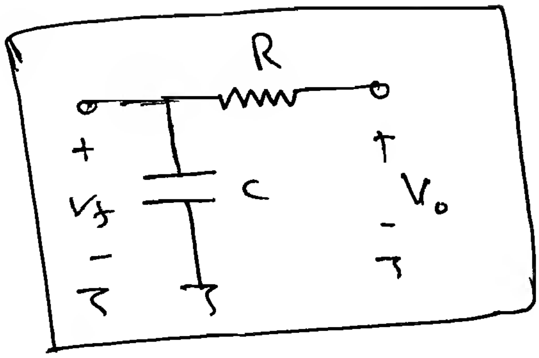
$$\therefore \quad \boxed{\frac{X}{Z} = \frac{\frac{1}{SC}}{R+\frac{1}{SC}}}.$$

$$\therefore \quad X = \left(\frac{\frac{1}{SC}}{\frac{1}{SC}+R}\right) Z.$$

$$\therefore \quad V_f = \left(\frac{\frac{1}{SC}}{R+\frac{1}{SC}}\right) V_o.$$



$\Rightarrow$



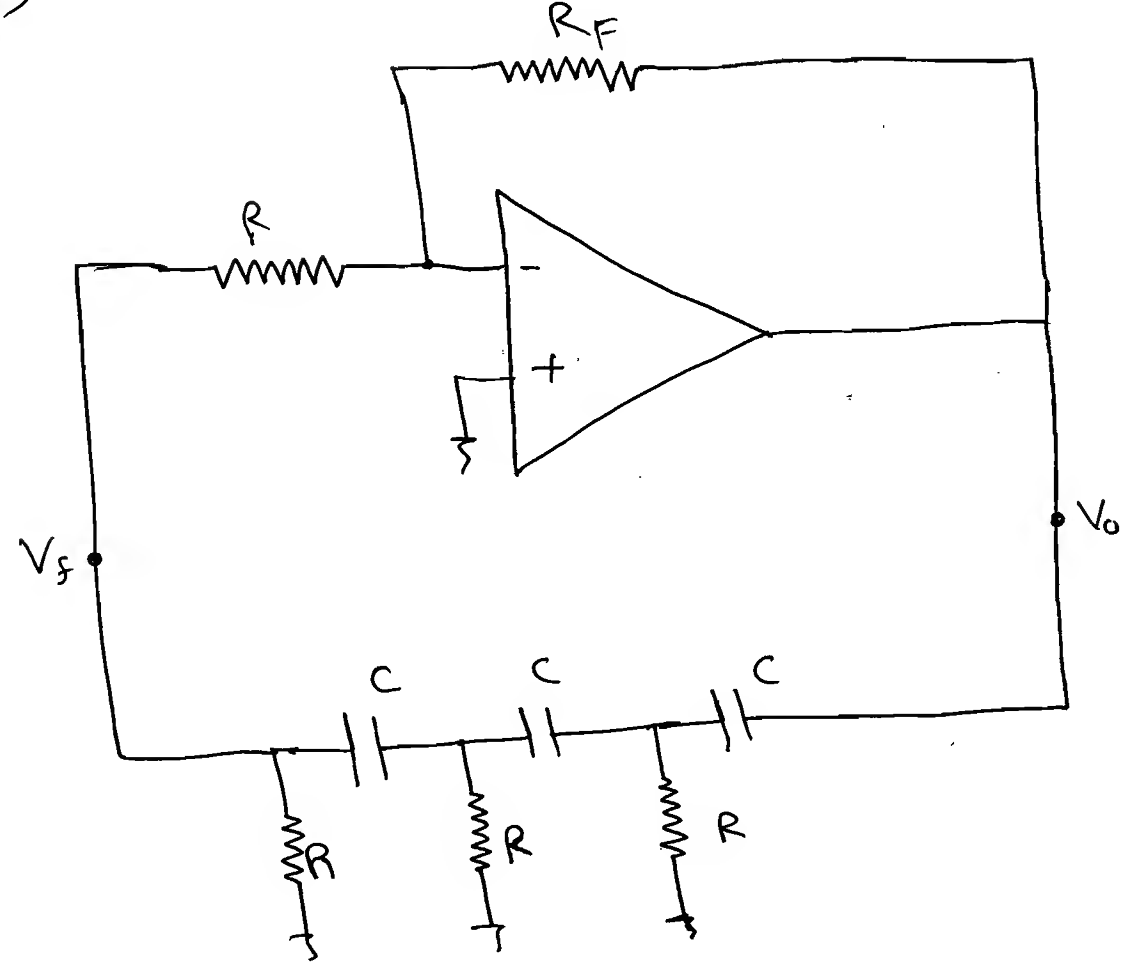
loop gain = 1

loop phase = 0°

So, it produce sinewave and it is nothing but Quadrature oscillator.

* Phase-shift oscillator :

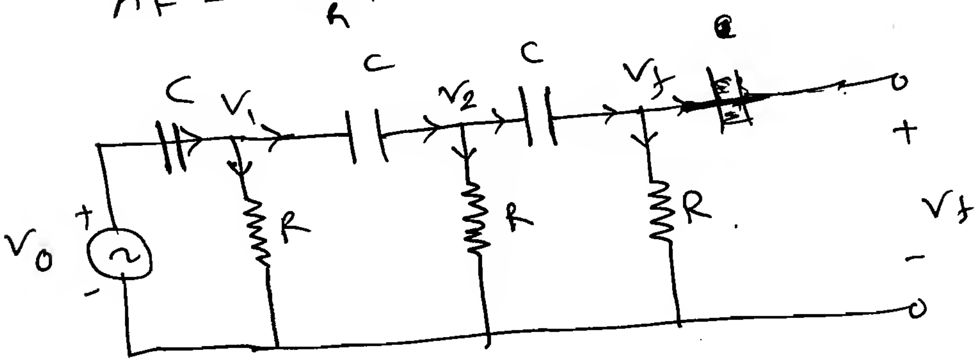
=>



* loop gain = 1.

$A\beta = 1 \Rightarrow \beta = 1/A_F$

$A_F = \frac{-R_F}{R}$.



KCL
at node V_1,

$\therefore sC(V_o - V_1) = \frac{V_1}{R} + sC(V_1 - V_2)$. — ①

$\therefore sC(V_1 - V_2) = \frac{V_2}{R} + sC(V_2 - V_f)$ — ②

$\therefore sC(V_2 - V_f) = \frac{V_f}{R}$ — ③

form - ③

$$\therefore V_2 = \left(1 + \frac{1}{RSC}\right) V_f$$

put V_2 in - ②

$$\therefore V_1 - V_2 = \frac{V_2}{RSC} + V_2 - V_f.$$

$$\therefore V_1 = \left(2 + \frac{1}{RSC}\right) V_2 - V_f.$$

$$\therefore V_1 = \left(2 + \frac{1}{RSC}\right)\left(1 + \frac{1}{RSC}\right) V_f - V_f.$$

$$\therefore V_1 = \left(2 + \frac{3}{RSC} + \frac{1}{R^2 s^2 C^2} - 1\right) V_f$$

$$\therefore V_1 = \left(1 + \frac{3}{RSC} + \frac{1}{s^2 R^2 C^2}\right) V_f$$

Now, form - ①

$$\therefore V_0 - V_1 = \frac{V_1}{RSC} + (V_1 - V_2)$$

$$\therefore V_0 = \left(2 + \frac{1}{RSC}\right) V_1 - V_2.$$

$$\therefore V_0 = \left[\left(1 + \frac{3}{RSC} + \frac{1}{s^2 R^2 C^2}\right)\left(2 + \frac{1}{RSC}\right) - \left(1 + \frac{1}{RSC}\right)\right] V_f.$$

$$\therefore V_0 = \left[2 + \frac{6}{RSC} + \frac{2}{S^2 R^2 C^2} + \cancel{\frac{1}{RSC}} + \frac{3}{R^2 s^2 C^2} + \frac{1}{R^3 C^3 s^3} - 1 - \cancel{\frac{1}{RSC}}\right] V_f.$$

$$\therefore V_0 = \left[1 + \frac{6}{RSC} + \frac{5}{s^2 R^2 C^2} + \frac{1}{s^3 R^3 C^3}\right] V_f$$

$$\therefore \quad \beta = \frac{V_f}{V_o}$$

$$\therefore \quad \beta = \frac{s^3R^3C^3}{1 + 5sCR + 6s^2R^2C^2 + s^3R^3C^3}.$$

Now, $\quad A = \frac{1}{\beta}.$

$$\therefore \quad \left(-\frac{R_F}{R_1}\right) = \frac{1 + 5sCR + 6s^2R^2C^2 + s^3R^3C^3}{s^3R^3C^3}.$$

$s = j\omega$

$$\therefore \quad -\frac{R_F}{R_1} = \frac{1 + j5\omega CR - 6\omega^2R^2C^2 - j\omega^3R^3C^3}{-j\omega^3R^3C^3}$$

$$\therefore \quad j\frac{R_F}{R_1} \times \omega^3R^3C^3 = (1 - 6\omega^2R^2C^2) + j(5\omega CR - \omega^3R^3C^3).$$

equate ~~Imag.~~ real part.

$$1 - 6\omega^2R^2C^2 = 0$$

$$\therefore \quad \omega^2R^2C^2 = 1/6.$$

$$\therefore \quad \boxed{f = \frac{1}{2\pi RC\sqrt{6}}}$$

equate Imag. part.

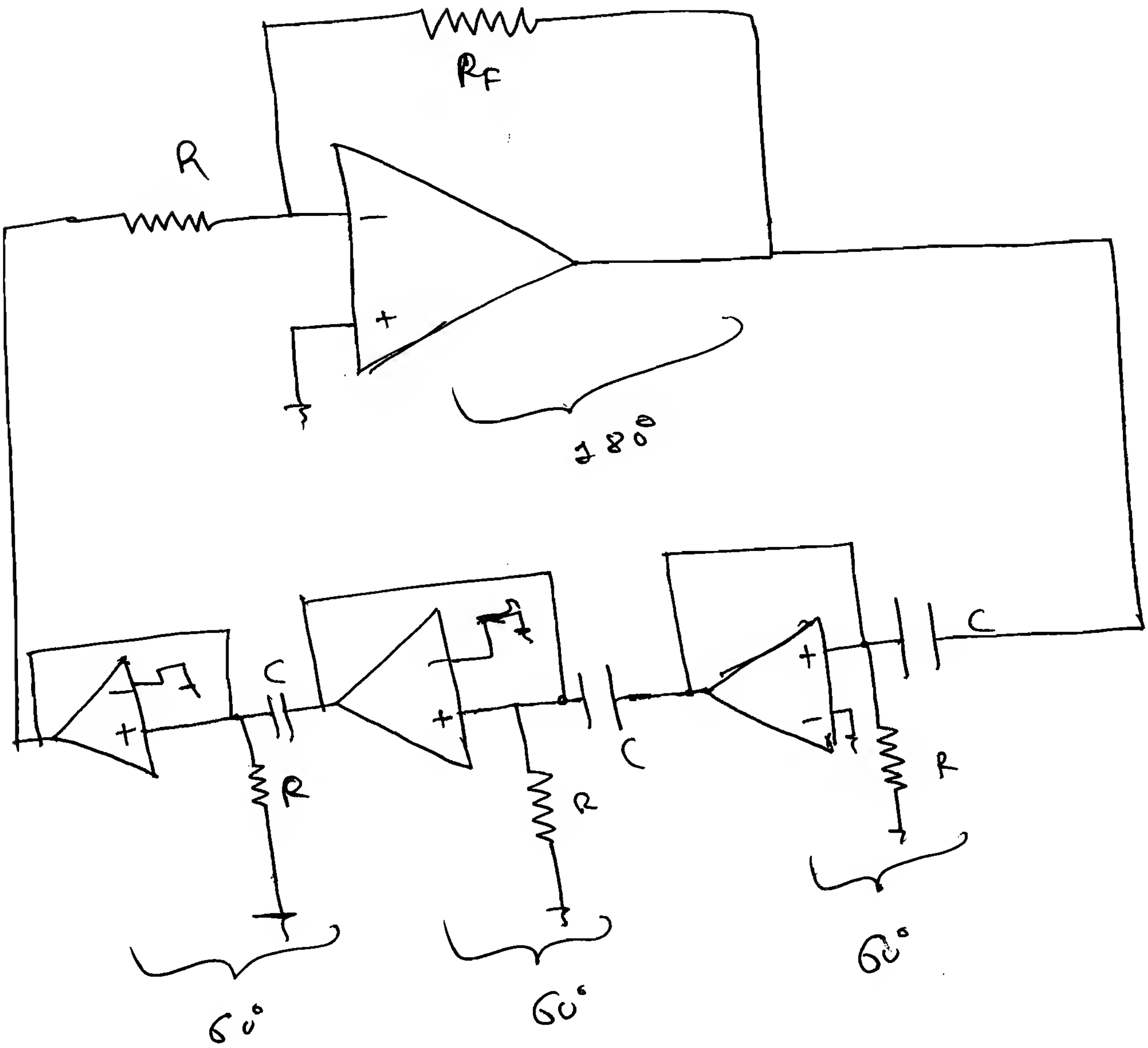
$$\therefore \quad \frac{R_F}{R_1} \times \omega^3R^3C^3 = 5\omega CR - \omega^3R^3C^3$$

$$\therefore \quad \frac{R_F}{R_1} \times \omega^2R^2C^2 = 5 - \omega^2R^2C^2.$$

$$\therefore \quad \frac{R_F}{R_1} = \frac{5}{\omega^2R^2C^2} - 1$$

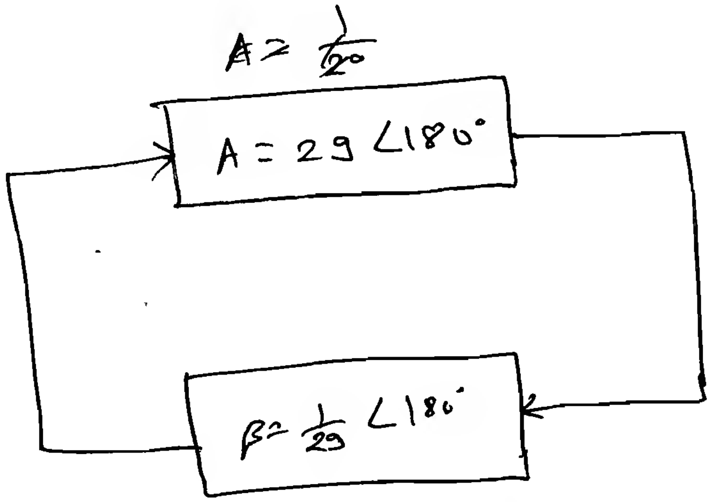
$$\therefore \quad R_F = (30 - 1)\,R_1. \Rightarrow \boxed{R_F = 29R_1}$$

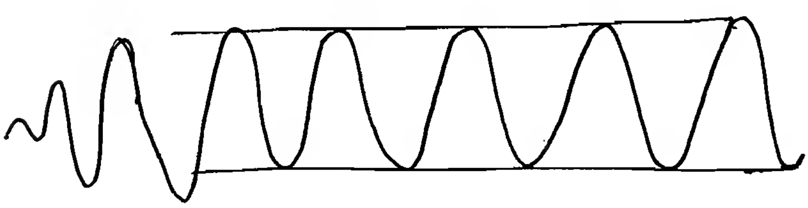
NOTE: phase shift oscillator



total loop phase = 360° or 0°.

→

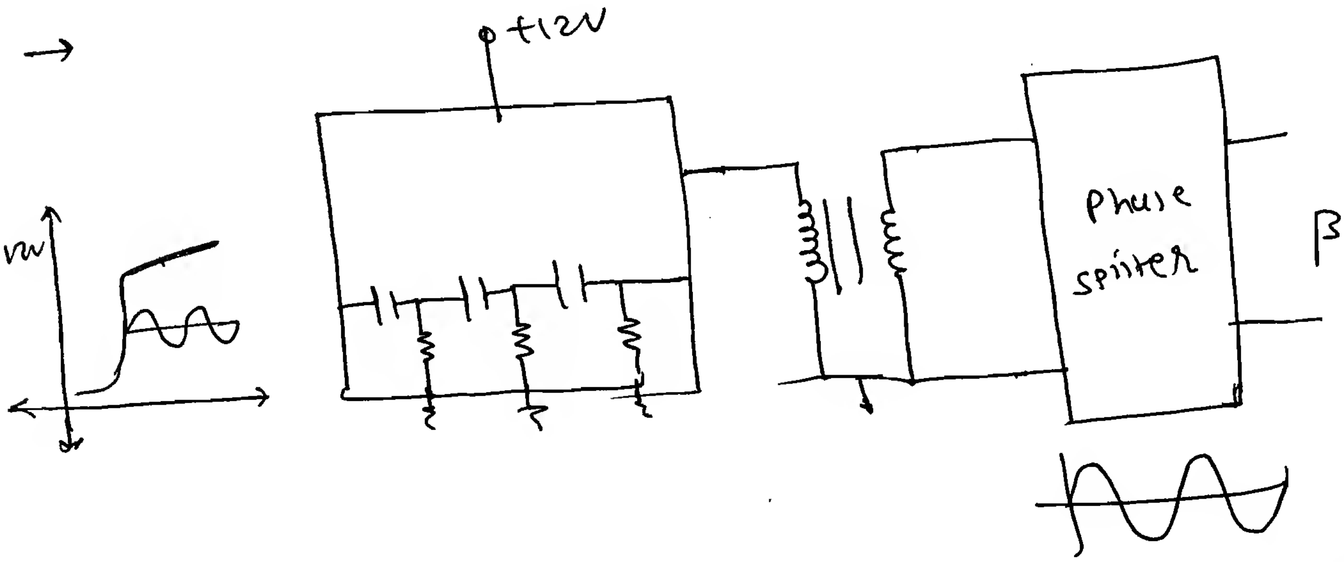




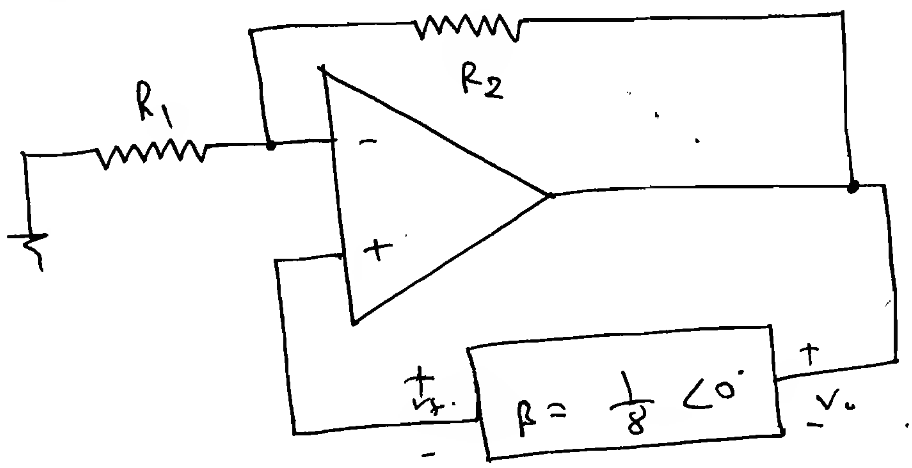
→ RC oscillator is used as a fixed audio freq. oscillator where as Wein bridge is a Variable freq. audio freq. oscillator.

→ For high freq. of oscillations we go for wide-band amplifiers with LC N/W.

→



Ex-1 Find the Relation betn R_1 & R_2 for sustained oscillation if $\beta = \frac{V_f}{V_o} = \frac{1}{8} \angle 0^\circ$.



$\therefore A = \left(1 + \frac{R_2}{R_1}\right)$. loop gain = 1 for sustained oscillation

$\therefore \beta = 1/8$. $\therefore A\beta = 1$.

$\therefore \left(1 + \frac{R_2}{R_1}\right)\frac{1}{8} = 1$

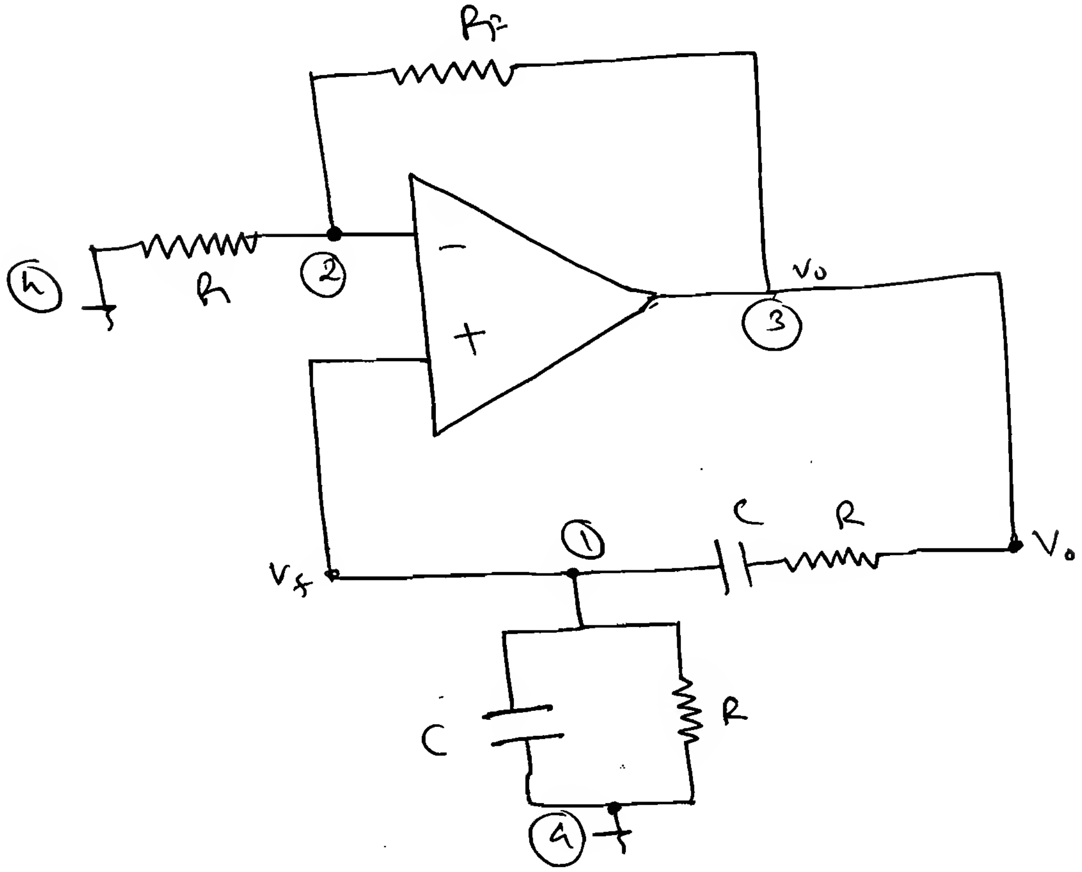
$$\therefore \left(1+\frac{R_2}{R_1}\right) = 8.$$

$$\therefore \left(1+\frac{R_2}{R_1}\right) = 8$$

$$\therefore \boxed{R_2 = 7R_1}$$

* Wein-Bidge oscillators:

⇒



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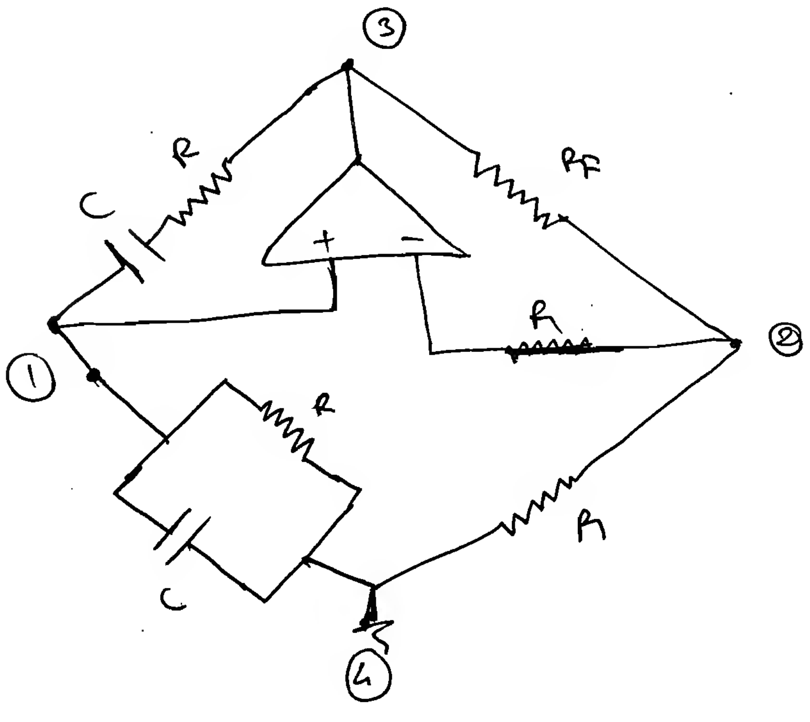
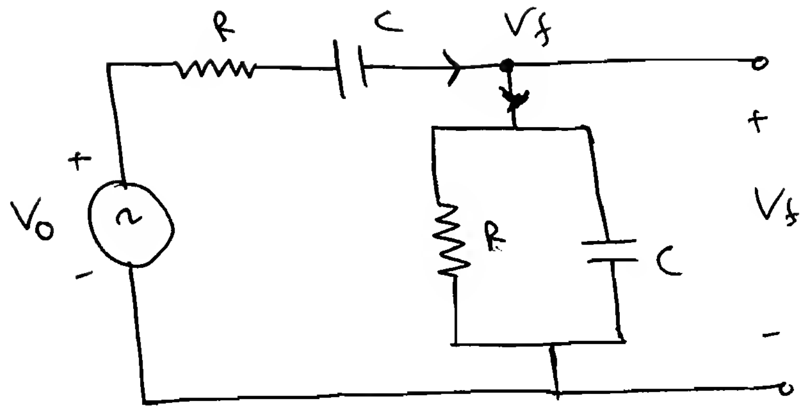


$\Rightarrow$



$$\Rightarrow \quad \frac{V_0 - V_f}{R + \frac{1}{sC}} = \frac{V_f}{R} + sCV_f.$$

$$sC(V_0 - V_f) = (1 + RsC)V_f\left[\frac{1}{R} + sC\right].$$

$$\therefore RsC(V_0 - V_f) = V_f\left[(1 + RsC)^2\right].$$

$$\therefore RsC(V_0 - V_f) = V_f\left[1 + 2RsC + s^2R^2C^2\right].$$

$$\therefore V_0 - V_f = V_f\left[2 + \frac{1}{R^2s^2C^2} + RsC\right].$$

$$\therefore V_0 = \left[3 + \frac{1}{R^2s^2C^2} + RsC\right]V_f.$$

$$\therefore \frac{V_f}{V_0} = \beta = \left(\frac{1 + 3R^2s^2C^2 + R^3s^3C^3}{R^2s^2C^2}\right)^{-1}.$$

$$\therefore A = \left(1 + \frac{R_F}{R}\right)$$

$s = j\omega.$

$$\therefore A = \frac{1}{\beta}.$$

$$\therefore 1 + \frac{R_F}{R} = \frac{R^2s^2C^2}{1 + 3R^2s^2C^2 + R^3s^3C^3}$$

$$\therefore 1 + 2\frac{R_F}{R}$$

$j\, s^2\omega$

$$\beta = \frac{1}{3 + j\left(\omega RC - \frac{1}{\omega RC}\right)}.$$

$\therefore$ $A.\beta = 1.$

$A = \frac{1}{\beta}.$

$\therefore$ $\left(1 + \frac{R_F}{R_1}\right) = 3 + j\left(\omega RC - \frac{1}{\omega RC}\right).$

$\therefore$ ~~$\frac{R_F}{R_1}$~~ cancel real part,

$\therefore$ $\frac{R_F}{R_1} = 2.$

$\therefore$ $\boxed{R_F = 2R_1}$

$$\omega RC = \frac{1}{\omega RC}.$$

$\therefore$ $\omega^2 = \frac{1}{R^2C^2}.$

$\therefore$ $\omega = \frac{1}{RC}.$

$\therefore$ $\boxed{f = \frac{1}{2\pi RC}}$

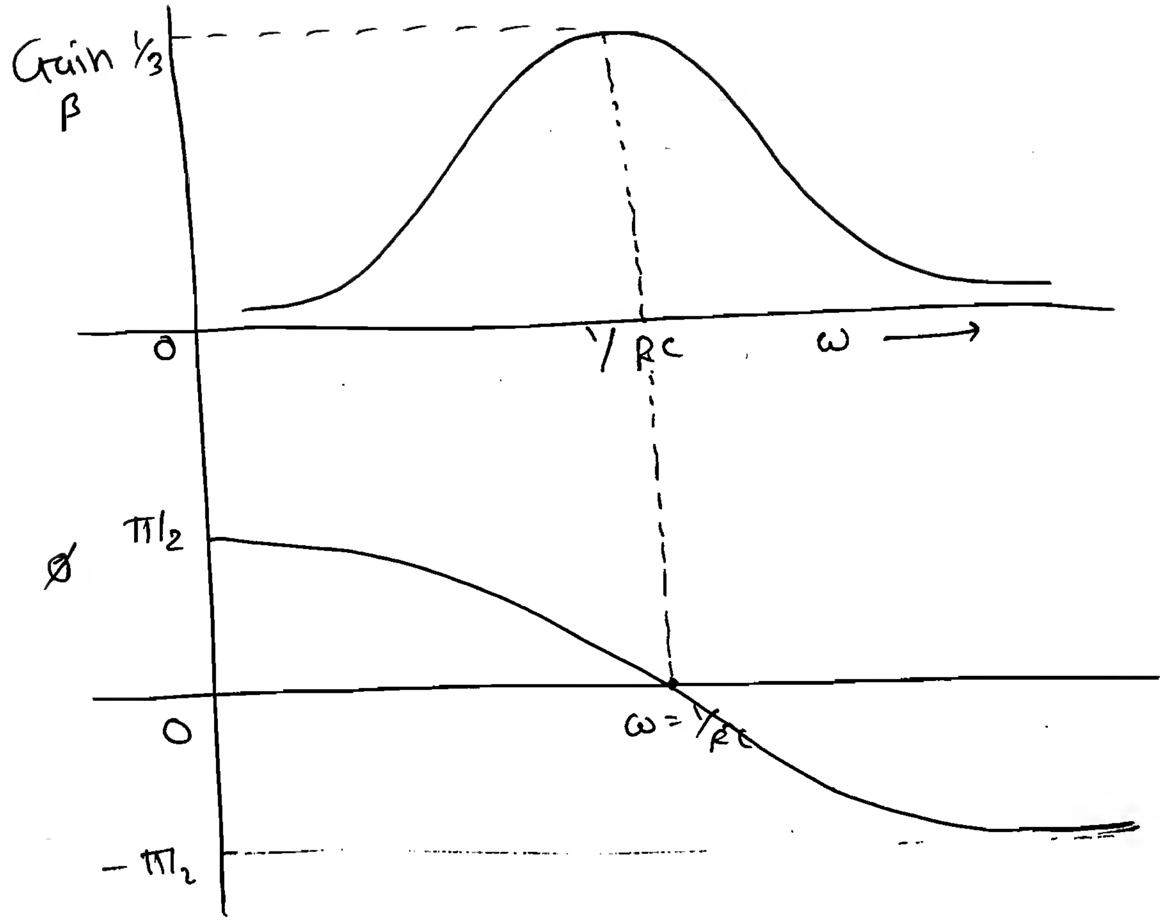
Now, $\beta = \frac{1}{3 + j\left(\omega RC - \frac{1}{\omega RC}\right)}.$

$$|\beta| = \frac{1}{\sqrt{9 + \left(\omega RC - \frac{1}{\omega RC}\right)^2}}.$$

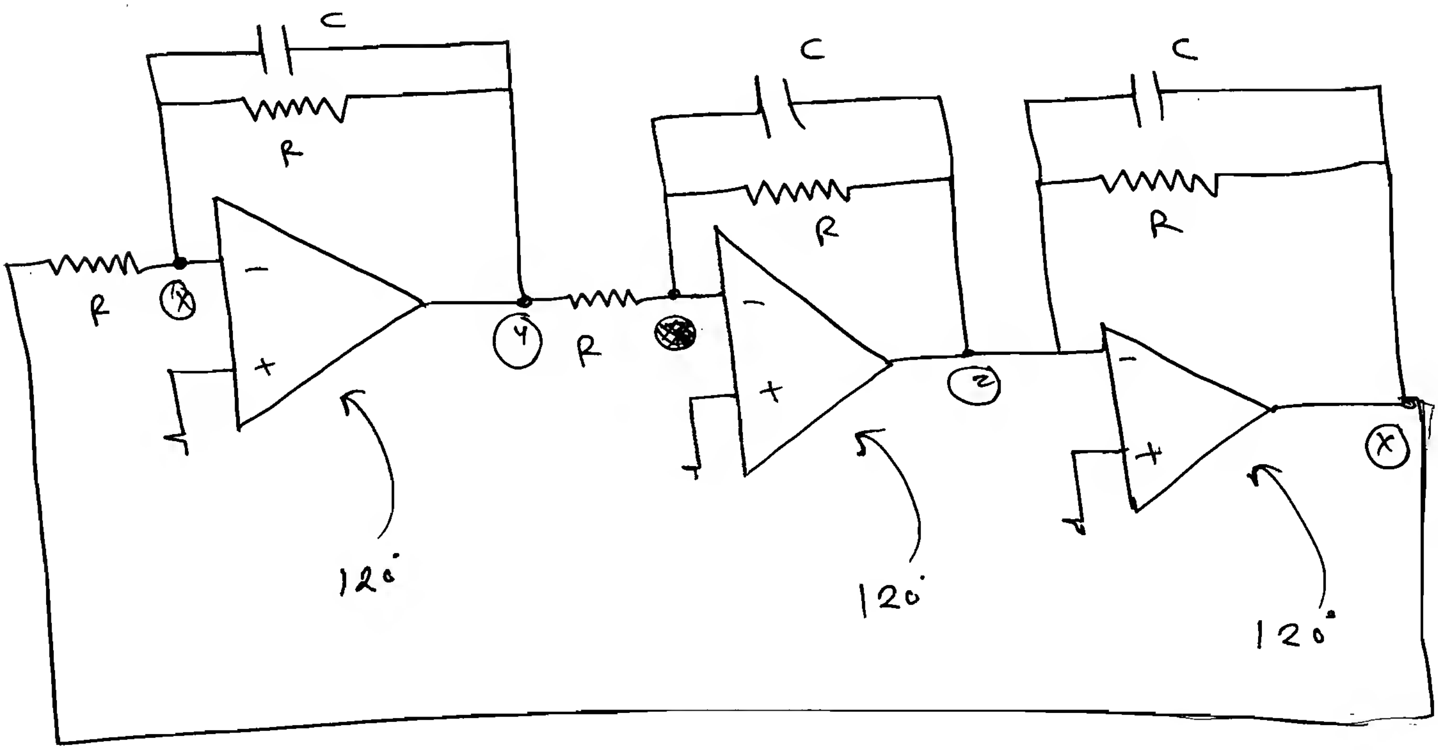
$\therefore$ $\angle \phi = -\tan^{-1}\left(\frac{\left(\omega RC - \frac{1}{\omega RC}\right)}{R}.\right).$

$\therefore$

ω	$\lvert\beta\rvert$	$\angle\phi$
0	∞	$+\pi/2$
$\frac{1}{RC}$	$1/3$	0
∞	0	$-\pi/2$



* 3- Phase oscillator:



⇒ loop-gain = 1.

$$\therefore \quad \frac{y}{x} \cdot \frac{z}{y} \cdot \frac{x}{z} = 1.$$

$$\therefore \quad \left(\frac{y}{x}\right)^3 = 1.$$

$$\therefore \frac{y}{x} = -\frac{R_F \| C}{R_1}$$

$\left(\frac{y}{x}\right)^3 \approx \phi$ at high freq. because c is 0 at high freq.

$$\therefore \frac{y}{x} = \frac{-1}{R_1}\left[\frac{R_F \times \frac{1}{sC}}{R_F + \frac{1}{sC}}\right]$$

$$\therefore \frac{y}{x} = \frac{-(R_F/R_1)}{1+sCR_F}.$$

$$\therefore \left(\frac{y}{x}\right)^3 = 1.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = (1+sCR_F)^3.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 + s^3C^3R_F^3 + 3sCR_F + 3s^2C^2R_F^2.$$

$$s = j\omega.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 - j\omega^3C^3R_F^3 + j3\omega CR_F - 3\omega^2C^2R_F^2.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 - 3\omega^2C^2R_F^2 - j\left(\omega^3C^3R_F^3 - 3\omega CR_F\right).$$

$\therefore$ cancel img. part,

$$\therefore \omega^3C^3R_F^3 = 3\omega CR_F.$$

$$3 = \omega^2C^2R_F^2.$$

$$\therefore \omega^2 = \frac{3}{R_F^2C^2}.$$

$$\therefore \boxed{f = \frac{\sqrt{3}}{2\pi R_F C}.}$$

Cancel Real part,

$$-\left(\frac{R_F}{R_1}\right)^3 = 1 - 3(3).$$

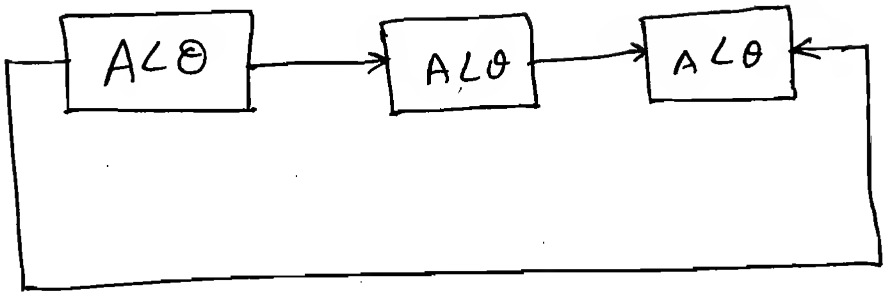
$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = -8$$

$$\left(\frac{R_F}{R_1}\right)^3 = 8.$$

$$\therefore \quad \frac{R_F}{R_1} = 2.$$

$$\therefore \quad \boxed{R_F = 2R_1}$$

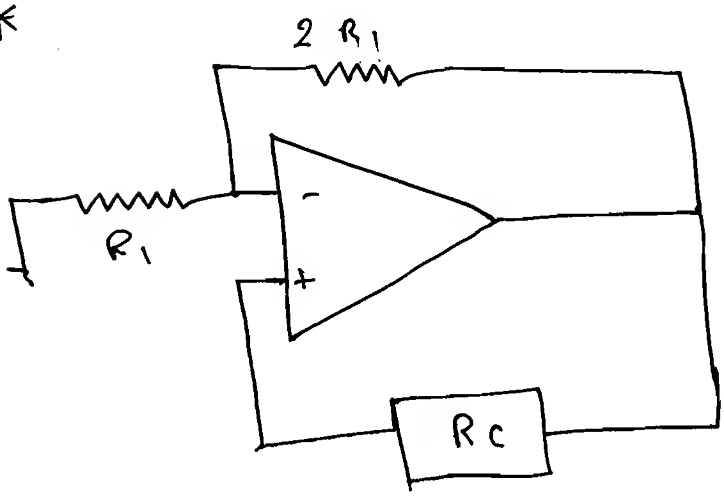
$\rightarrow \quad A^3 \angle 3\theta = 1 \angle 360^\circ.$

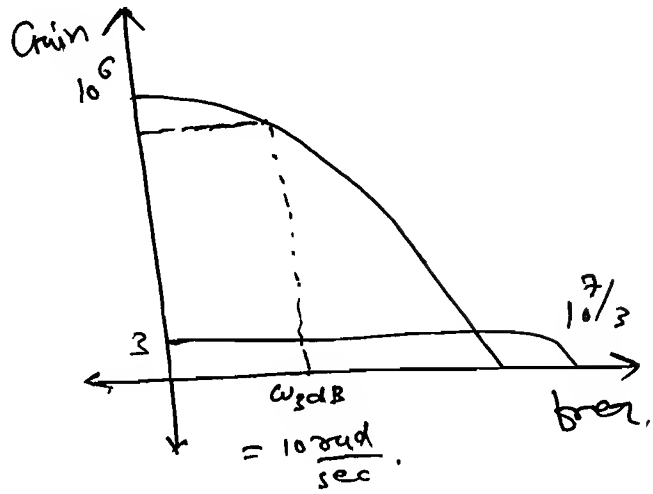


$$3\theta = 360^\circ.$$

$$\therefore \quad \boxed{\theta = 120^\circ}$$

*





$\rightarrow \quad \text{Gain} = \dfrac{10^6}{1+\frac{s}{10}} = \dfrac{A_0}{1+\frac{s}{\omega_{3dB}}}.$

$$\beta = \frac{R_1}{R_1+R_F}$$

$$\boxed{\beta = 1/3}$$

$$\therefore \quad A_F = \frac{A}{1+A\beta}.$$

$$\therefore \quad A_F = \frac{\frac{10^6}{1+\frac{s}{10}}}{1+\frac{1}{3}\left(10^6/1+s/10\right)}.$$

$$\therefore \quad A_F = \frac{3\times10^6}{3+\frac{3S}{10} +10^6}$$

$$A_F = \frac{3}{1+\frac{3S}{10^7}}.$$

$$\therefore \quad A_F = \frac{3}{1+\frac{S}{(10^7/3)}} = \frac{3}{1+j\frac{3\omega}{10^7}}$$

Now, phase of RC oscillator is

$$\phi = -\tan^{-1}\left[\frac{\omega^2R^2C^2-1}{3\omega RC}\right].$$

let $x = \frac{\omega^2R^2C^2-1}{3\omega RC}$.

$$\therefore \quad \frac{d\phi}{d\omega} = \frac{-1}{1+x^2} \cdot \frac{dx}{d\omega}$$

$$\therefore \quad \frac{dx}{d\omega} = \frac{3\omega RC\,(2\omega R^2C^2) - (\omega^2R^2C^2-1)(3RC)}{9\omega^2R^2C^2}.$$

$$\therefore \quad \frac{d\phi}{d\omega} = \frac{6\omega^2R^3C^3 - 3\omega^2R^3C^3 + 3RC}{9\omega^2R^2C^2}.$$

at $\omega = 1/RC$.

$$\therefore \quad \frac{d\phi}{d\omega} = \frac{2}{3\omega}.$$

Now, Phase lag suffered by amp. is

$$(\Delta\phi) = -\tan^{-1}\left(\frac{3\omega}{10^7}\right) \simeq \frac{3\omega}{10^7}.$$

→ Phase lag is compensated by RC N/w at a rate $\frac{d\phi}{d\omega} = \frac{2}{3\omega}$.

$\therefore$

$\therefore$ Variation of freq.

$$d\omega = \frac{3\omega}{2} \cdot d\phi .$$

$$\therefore d\omega = \frac{3\omega}{2} \cdot \frac{3\omega}{107} .$$

$$\therefore d\omega = \frac{4.5\,\omega^2}{107} .$$

Now, at low freq say 1KHz.

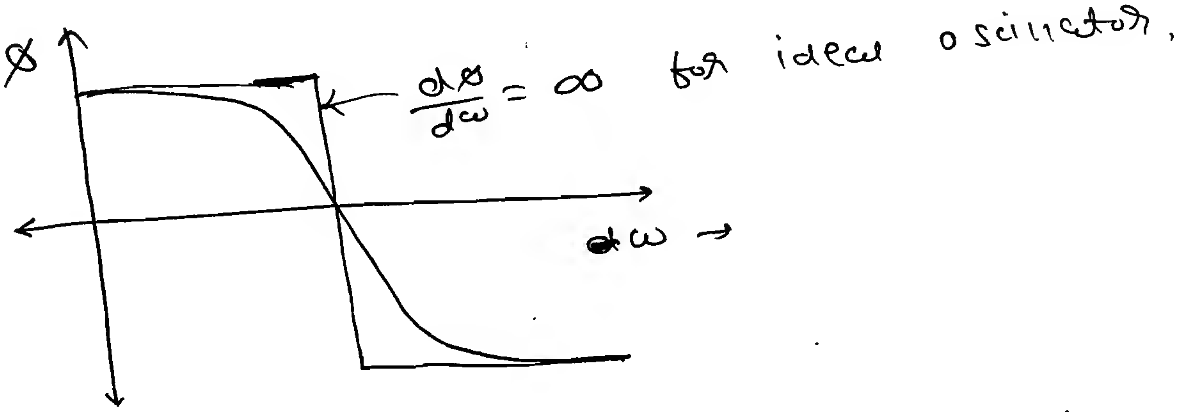
$$\therefore d\omega = \frac{4.5 \times 10^6}{107} = 0.45 \text{ rad/sec (stable)}.$$

but at high freq say 100 KHz.

$$\therefore d\omega = \frac{4.5 \times 10^{10}}{107} = 4.5k \text{ rad/sec}$$
$$= 4.5\% \text{ error}.$$

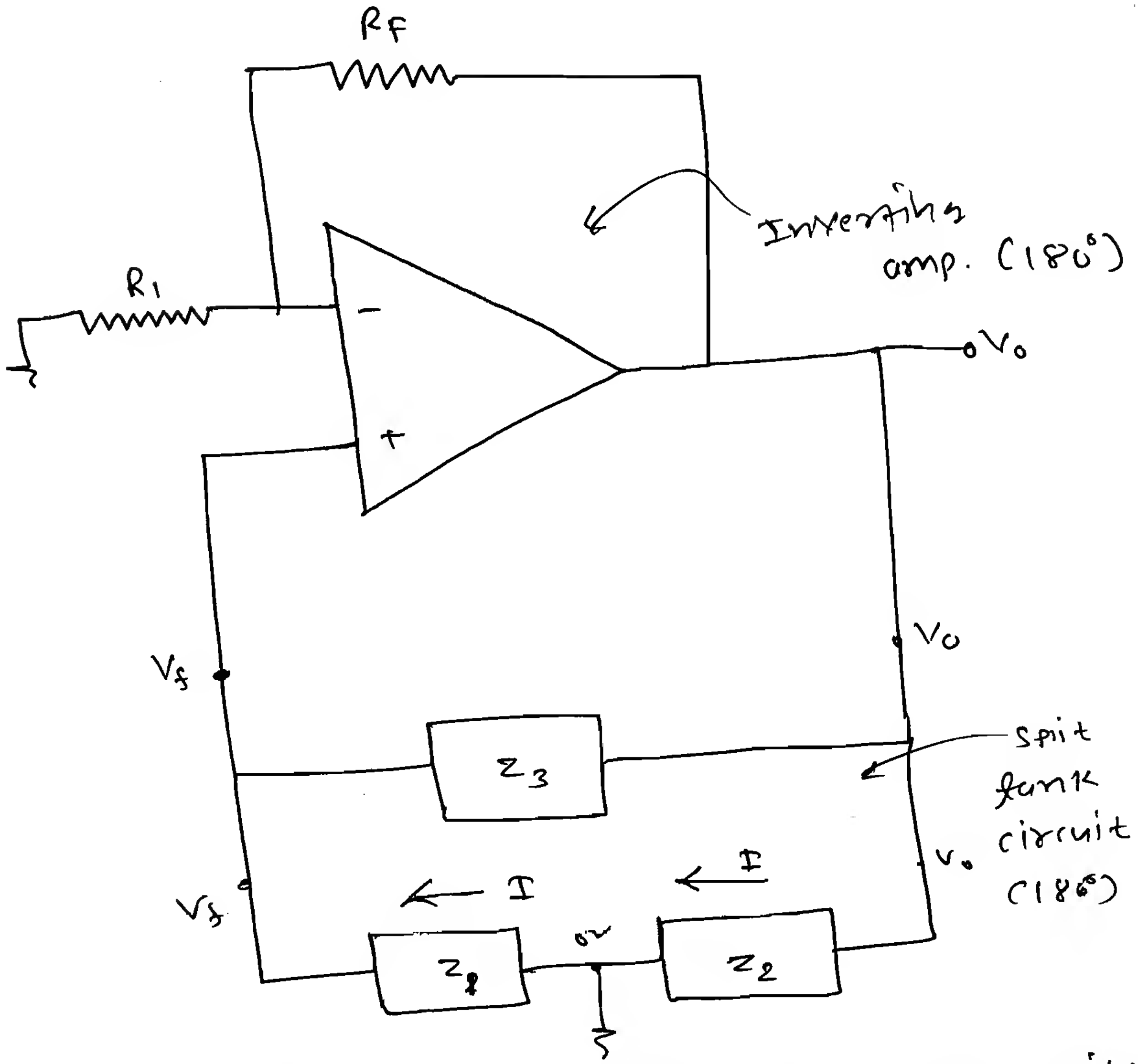
for good oscillator

$$\left|\frac{d\phi}{d\omega}\right| \propto \infty .$$



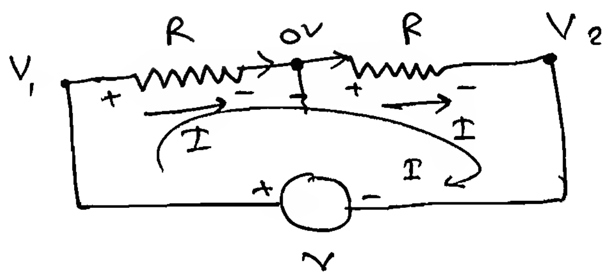
→ We conclude that RC N/W suffer from this major disadvantage that their phase verses freq. response is very poor. For high freq. of 100K rad/sec there is error of 4.5 % [i.e. 4.5 K rad/sec] . so we go for wide band amplifiers with LC network for high freq. of oscillation.

* General Configuration of LC oscillator:



→ Ground in middle we get 180° phase shift.

①

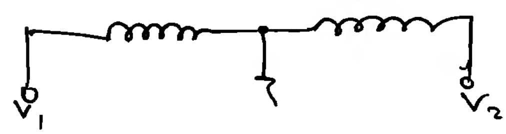


$\Rightarrow \quad I = \dfrac{V}{2R}$.

$$\therefore \quad I = \frac{V_1 - 0}{R} = \frac{0 - V_2}{R}$$

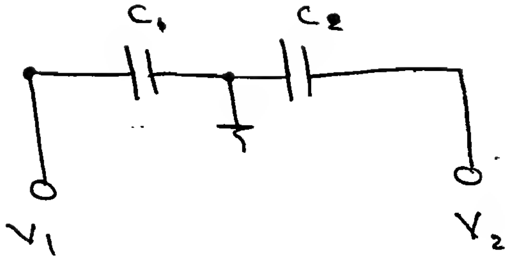
$$\Rightarrow \quad \boxed{V_1 = -V_2}$$

②



$\Rightarrow \quad \boxed{V_1 = -V_2}$

3



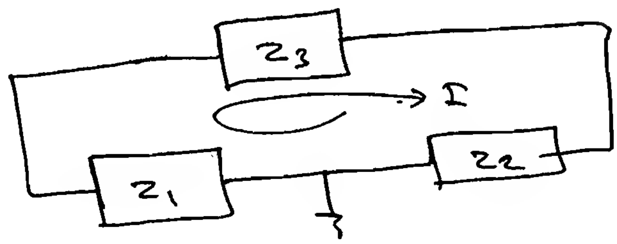
$\Rightarrow \boxed{V_1 = -V_2}$

$$\therefore \quad I = \frac{V_0 - 0}{Z_2} = \frac{0 - V_f}{Z_1}.$$

$$\therefore \quad \boxed{\frac{V_f}{V_0} = -\frac{Z_1}{Z_2} = \beta.} \qquad \beta = \left|\frac{Z_1}{Z_2}\right| \angle 180^\circ.$$

$$\Rightarrow \quad A = \frac{1}{\beta} = -\frac{Z_2}{Z_1} = -\frac{R_F}{R_1}.$$

$$\therefore \quad \boxed{\frac{R_F}{R_1} = \frac{Z_2}{Z_1}.}$$



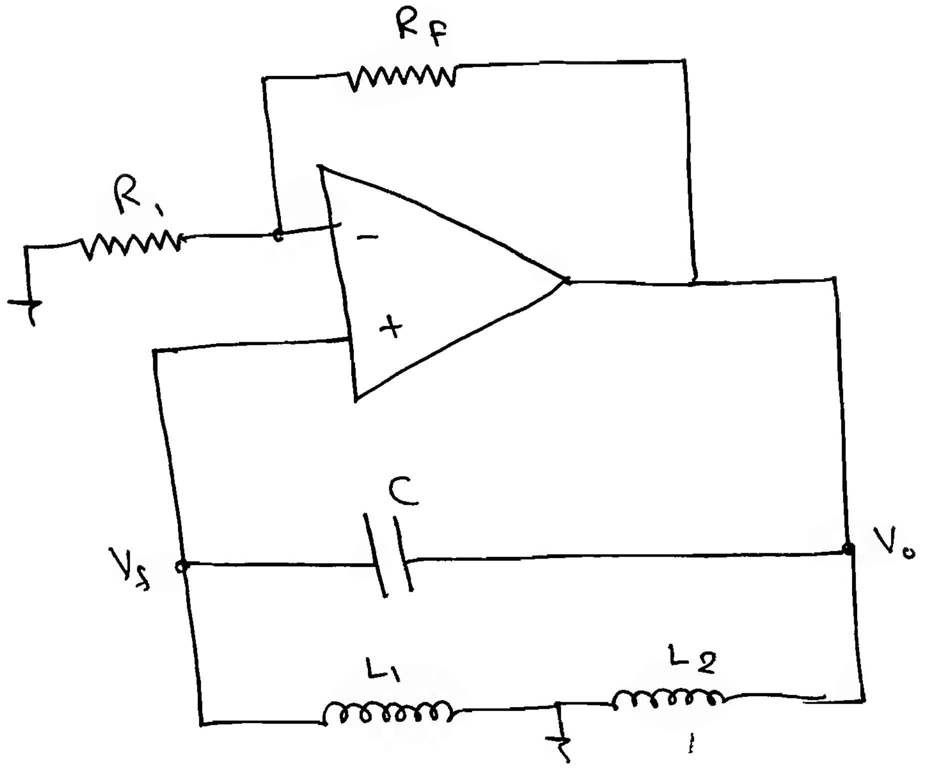
$$\therefore \quad I\,(Z_1 + Z_2 + Z_3) = 0$$

$$\therefore \quad \boxed{Z_1 + Z_2 + Z_3 = 0}$$

This is used for finding frequency.

* Hartley oscillator:

→ Take $Z_3 = C$, $Z_1 = L_1$, $Z_2 = L_2$.



→ ① $\beta = \dfrac{V_f}{V_o}$

② $Z_1 + Z_2 + Z_3 = 0$.

$\therefore j\omega L_1 + j\omega L_2 + \dfrac{1}{j\omega C} = 0$

$\therefore j\omega (L_1 + L_2) = -\dfrac{1}{j\omega C}$.

$\therefore \omega (L_1 + L_2) = \dfrac{1}{C}$

$\therefore \omega = \dfrac{1}{C(L_1 + L_2)}$

$\therefore \boxed{f = \dfrac{1}{2\pi \sqrt{C L_{eq}}}}$ where, $L_{eq} = L_1 + L_2$.

$\therefore \dfrac{R_F}{R_1} = \dfrac{Z_2}{Z_1}$.

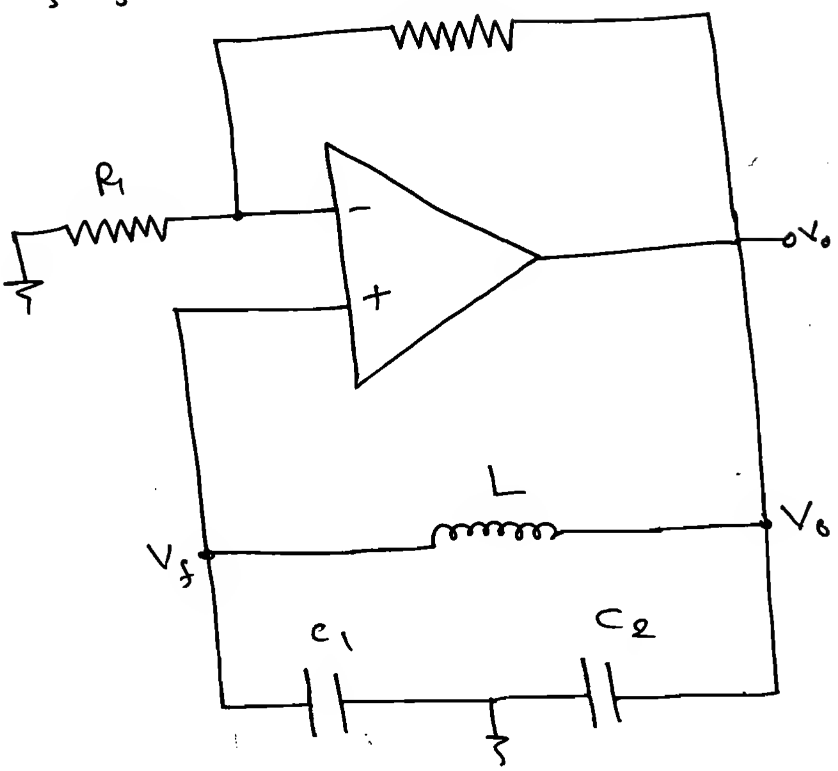
$\therefore \dfrac{R_F}{R_1} = \dfrac{j\omega L_2}{j\omega L_1}$. $\Rightarrow$ $\boxed{\dfrac{R_F}{R_1} = \dfrac{L_2}{L_1}}$.

* Colpitts oscillators:

=> Take $z_1 = 1/j\omega C_1$

$z_2 = 1/j\omega C_2$

$z_3 = j\omega L$



=> ① $z_1 + z_2 + z_3 = 0$.

$\therefore \quad j\omega L + \dfrac{1}{j\omega C_1} + \dfrac{1}{j\omega C_2} = 0$

$\therefore \quad \omega L = \dfrac{1}{\omega C_1} + \dfrac{1}{\omega C_2}$.

$\therefore \quad \omega^2 = \dfrac{1}{L\left[\frac{1}{C_1} + \frac{1}{C_2}\right]}$.

$\therefore \quad \omega = \dfrac{1}{\sqrt{L C_{eq}}}$.

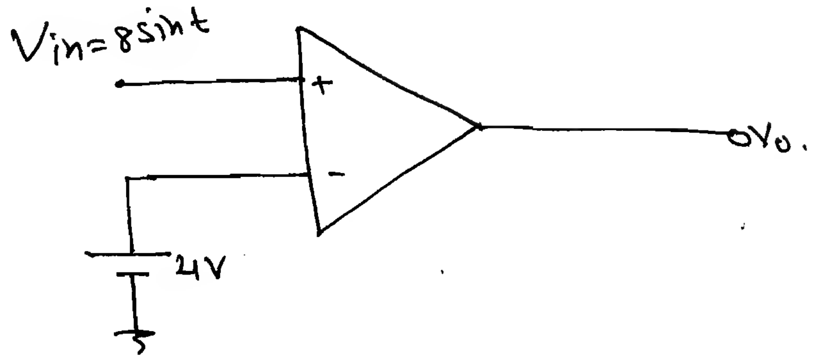
$\therefore \quad \boxed{f = \dfrac{1}{2\pi\sqrt{C_{eq} L}}}$ where $C_{eq} = \dfrac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$

② $\dfrac{R_F}{R_1} = \dfrac{z_2}{z_1}$.

$\therefore \quad \dfrac{R_F}{R_1} = \dfrac{\frac{1}{j\omega C_2}}{\frac{1}{j\omega C_1}} = \dfrac{C_1}{C_2}$. => $\boxed{\dfrac{R_F}{R_1} = \dfrac{C_1}{C_2}}$.

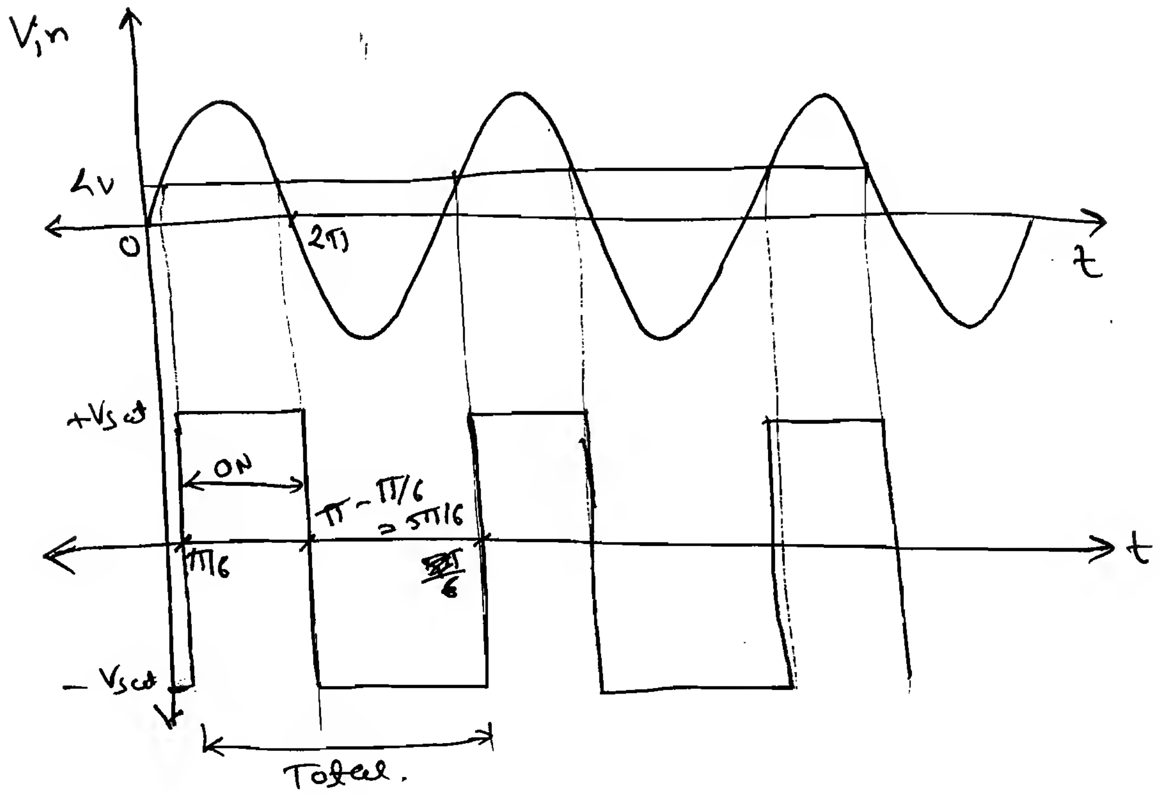
Ex-1 Calculate the duty cycle of the O/P of Comparators given.

Ans:



$\therefore$ $8\sin t > 4 \Rightarrow V_o = +V_{sat}$

$8\sin t < 4 \Rightarrow V_o = -V_{sat}$.



$\therefore$ $8\sin t = 4$.

$\therefore$ $\sin t = \frac{1}{2}. \Rightarrow t = \frac{\pi}{6}$.

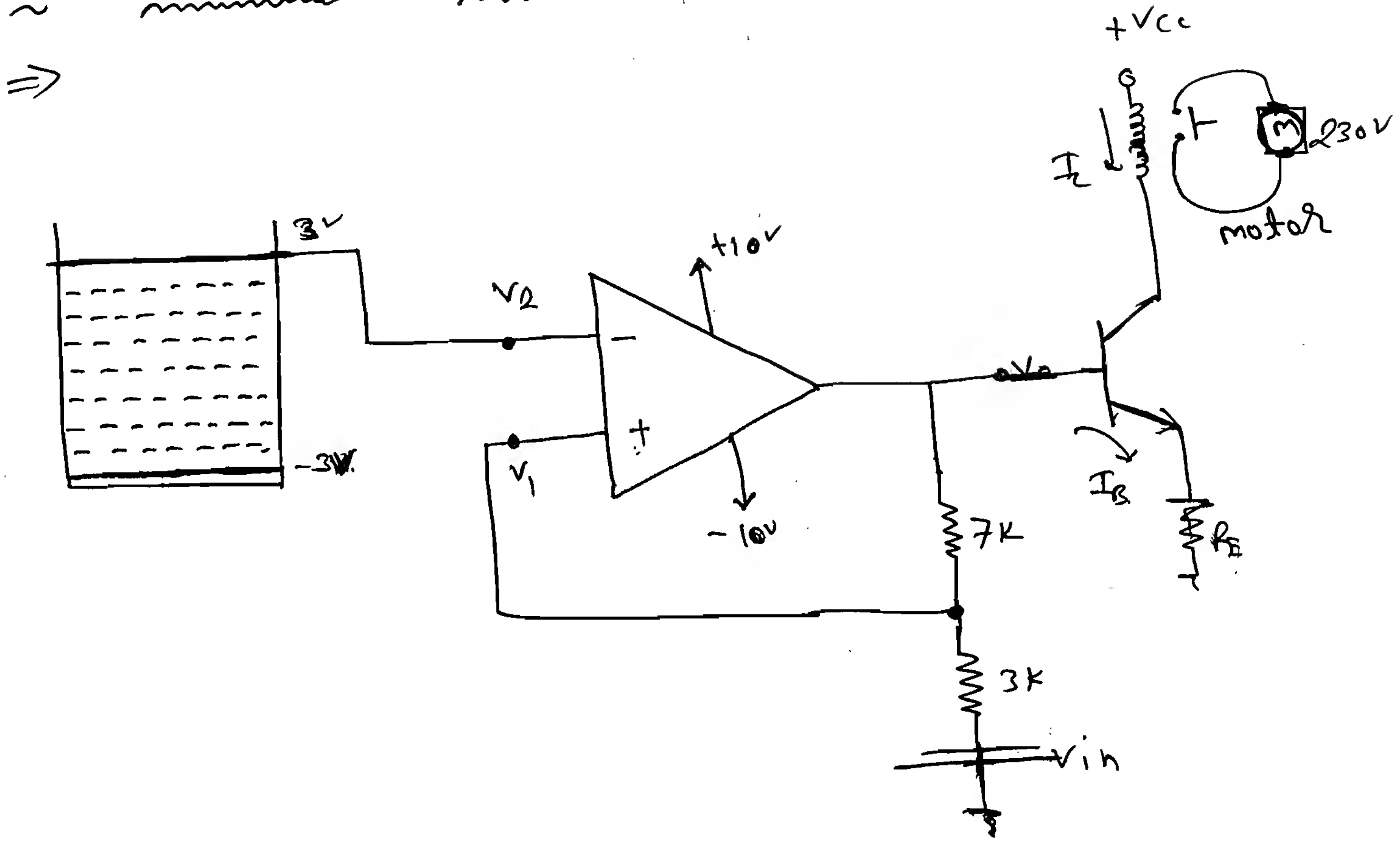
$\therefore$ Duty cycle $= \frac{T_{ON}}{Total}$

$$= \frac{\frac{5\pi}{6} - \frac{\pi}{6}}{2\pi}$$

$\therefore$ $\boxed{\text{Duty cycle} = \frac{1}{3}}$

* Schmitt trigger:

⇒



→ Let, there is a over head water tank which is automatically filled when it is empty by switching on the motor.

→ Let, there are two ~~threshold~~ voltage +3V which is ~~correspond~~ ~~to~~ indicate tank is full with water. and -3V which is indicate tank is empty.

→ Now, consider initial tank is empty, therefor we have to start motor. ~~For~~ To Do so BJT should be on. for that output of OP-Amp is $+V_{sat}$.

⇒ So, we conclude that at initial voltage at V_2 is -3V. (tank is empty) and at

$V_1 = +3V$ (By voltage divider $V_1 = \frac{3}{10} \times 10) = 3V$).

→ Now, as motor on, tank will start to fill with water and corresponding voltage level also increase. (from $-3V$ to $+3V$). During this period voltage at V_0 is remain $+V_{sat}$ because $(V_1 > V_2)$ and at V_1 voltage is still $+3V$.

→ Now, as soon as V_2 reaches to $+3$ $V_1 = V$ $V_{id} = 0$ so voltage $V_1 = V_2$ and as soon as tank will totally $V_0 = -V_{sat}$. as soon as $V_2 = -3V$. as water fulled with water start to increase more V_2 start to increase above $+3V$. Now, as $V_2 > +3V$, $V_1 - V_2 = -ve$ and output switch from $+V_{sat}$ to $-V_{sat}$. This thing switch off the BJT and it will in turn switch off the motor.

⇒ Now, $V_1 = -3V$ ($\because$ $V_1 = \frac{3}{10} \times (-V_{sat}) = -3V$).

& $V_2 = +3V$.

⇒ Now, as the water in tank start to decrease, but decrease V_1 also start to decrease, but $V_0 = +V_{sat}$ still and $V_2 = +3V$ still and motor is off still.

⇒ Now, when ~~water~~ tank is completly empty. $V_2 = -3V$, $V_1 = -3V$ but when water is below the $-3V$ i.e. $V_2 < -3V$. ⇒ $V_1 - V_2 = +ve$.

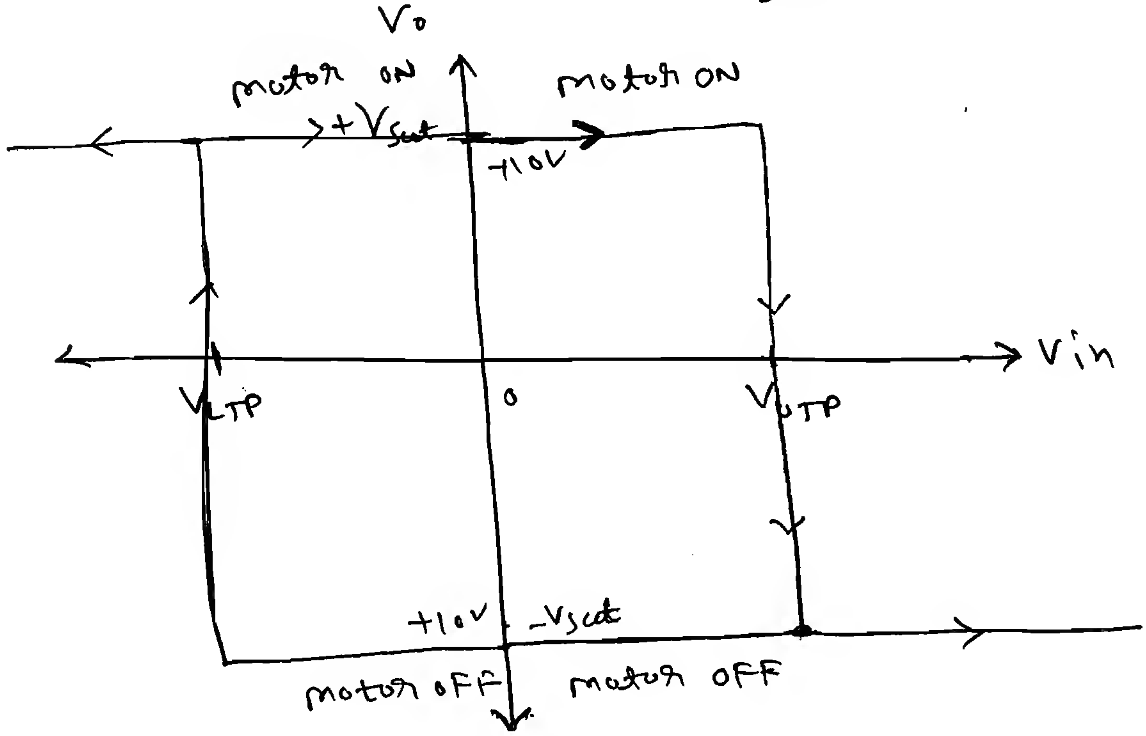
⇒ This will ~~change~~ to switch V_o from ~~st~~ $-V_{sat}$ to $+V_{sat}$. This will in turn on the motor and tank will again start to fill with water. at this state

V_2 start increasing from (-3 to 3V) and
$V_1 = -3V$.

⇒ we can conclud that $+3V$ is UTP and $-3V$ LTP.

→ when $V_{in} > V_{UTP}$, $V_{in} > 3V$ ⇒ motor is on. as V_o switch from $-V_{sat}$ to $+V_{sat}$.

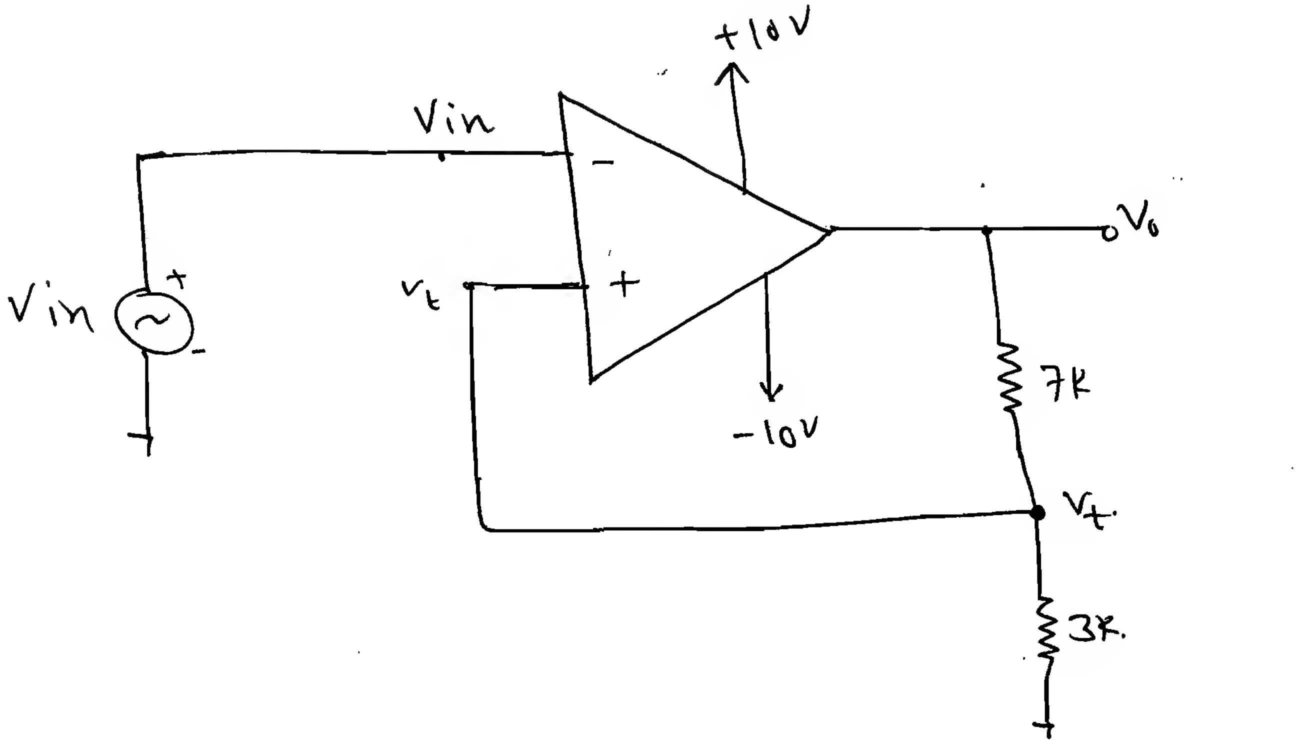
→ when $V_{in} < V_{LTP}$, $V_{in} < -3V$ ⇒ motor will OFF as ~~and~~ V_o switch from $+V_{sat}$ to $-V_{sat}$.



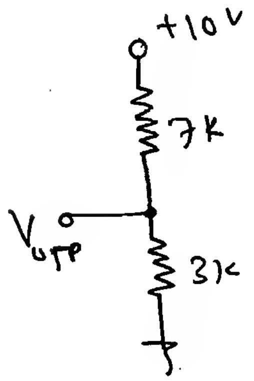
→ when $V_{LTP} < V_{in} < V_{UTP}$ ⇒ V_o donot change its state.

$\boxed{\text{Hysteresis width} = V_{UTP} - V_{LTP}}$.

Ex-1 Calculate UTP & LTP and Hysteresis width.



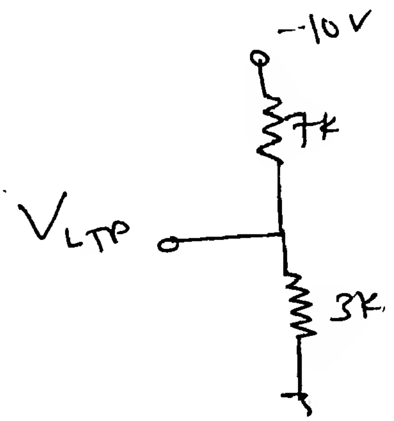
→ $V_t = V_{UTP}$ when $V_o = +10V$



$$V_{UTP} = \frac{V_o \times 3K}{10K}$$

$\therefore \boxed{V_{UTP} = 3V}$

→ $V_t = V_{LTP}$ when $V_o = -10V$



$$V_{LTP} = \frac{3}{10} \times (-10).$$

$\boxed{V_{LTP} = -3V}$

→ Hysteresis width:

$HW = V_{UTP} - V_{LTP}$

$\therefore HW = 3 - (-3V)$

$\therefore \boxed{HW = 6V}$

→ when $V_o = +V_{sat}$. $\frac{D_1 \text{ is on}}{D_2 \text{ is OFF}}$ cond.

$V_t = V_{UTP}$

$V_E = V_{UT}$

$= \frac{\cancel{6}}{18\,\cancel{3}} \times +\cancel{12}\,4$

$\boxed{V_{UTP} = 4V}$

→ when $V_o = -V_{sat}$ D_1 is OFF & D_2 is ON

$\therefore V_t = V_{LTP}$.

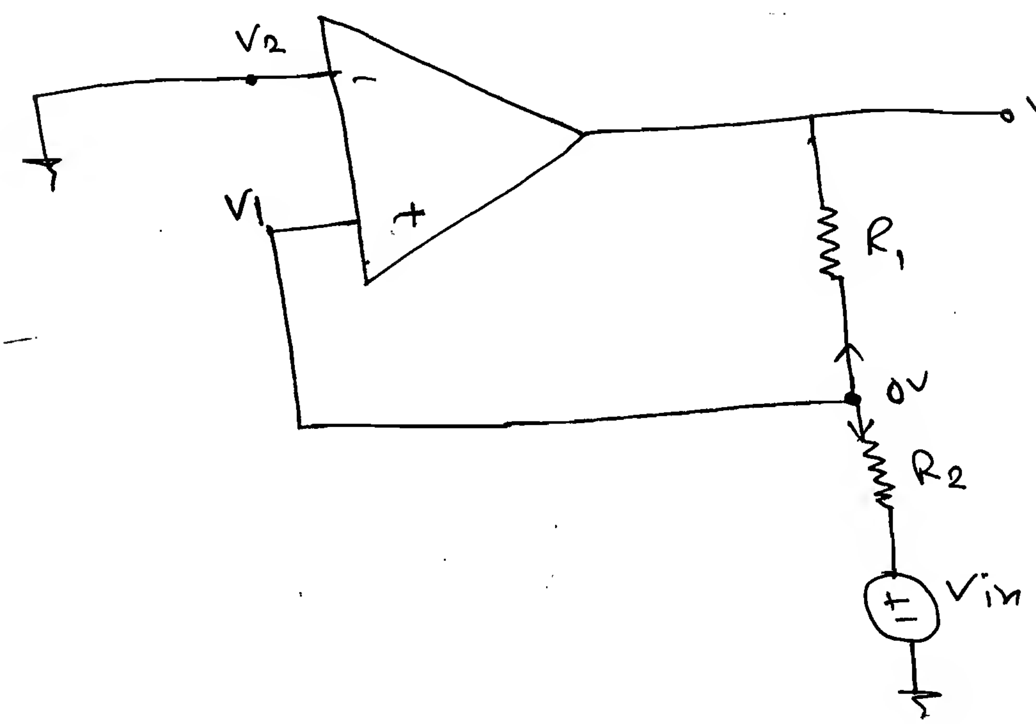
$= \frac{\cancel{6}\,2}{\cancel{9}\,3} \times (-\cancel{12})\,4$

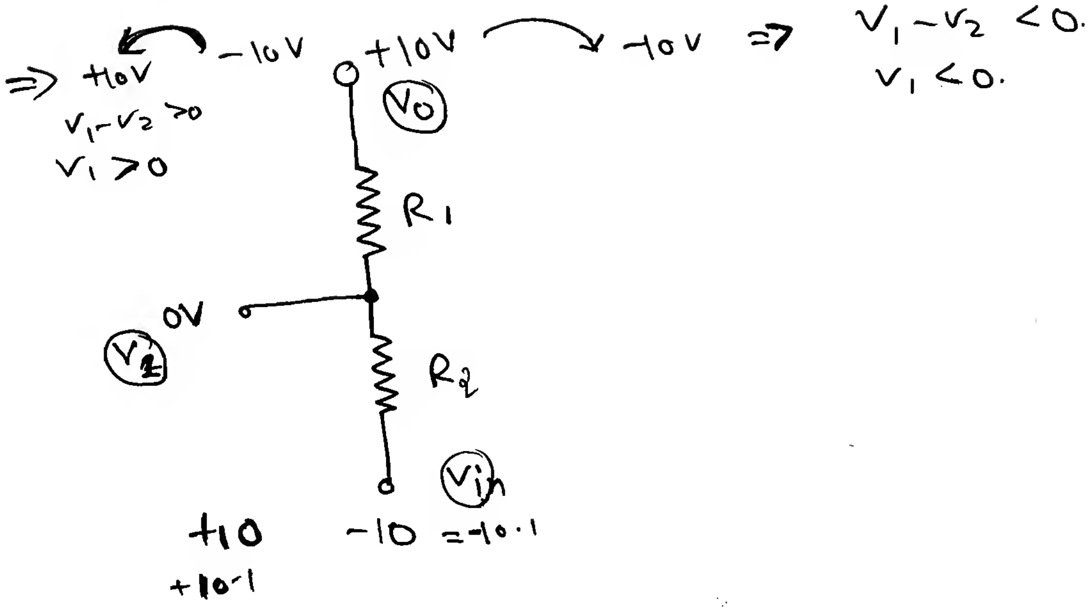
$\therefore \boxed{V_{LTP} = -8\,V}$

$\therefore HW = V_{UTP} - V_{LTP}$

$\therefore HW = 4 - (-8) = 12V.$

* Non-inverting Schimtt trigger:

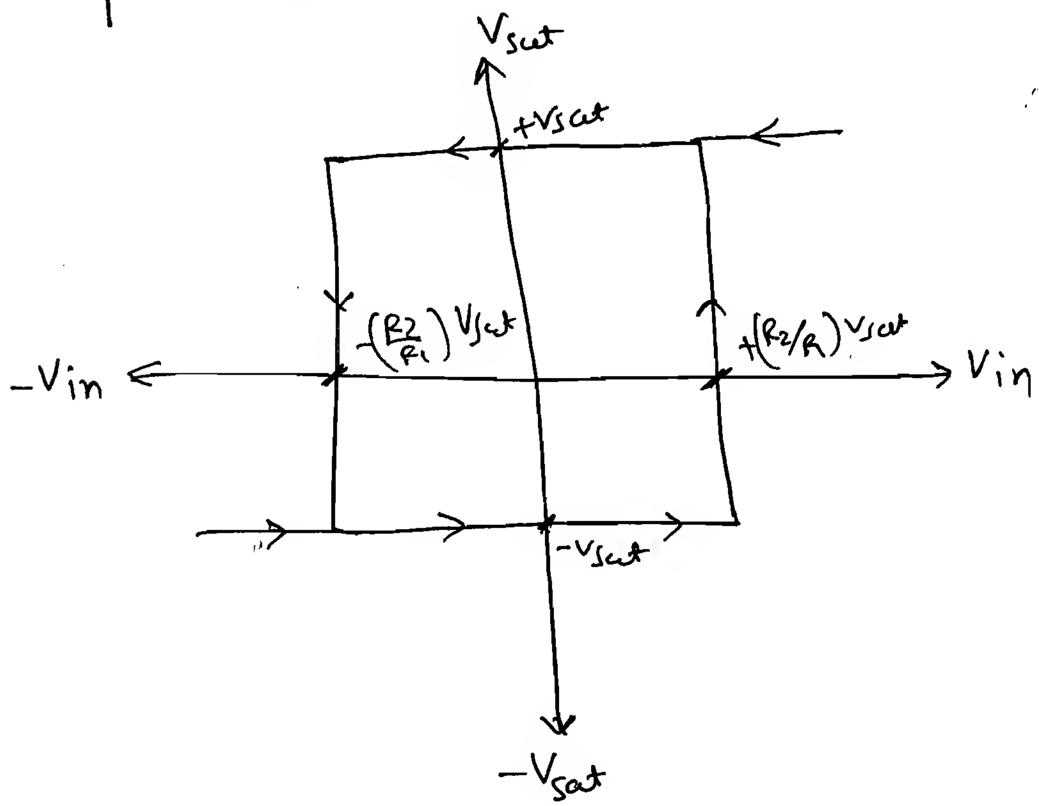




$$\therefore \frac{0 - V_o}{R_1} = \frac{0 - V_{in}}{R_2}.$$

$$\therefore \boxed{V_{in} = -\left(\frac{R_2}{R_1}\right) \cdot V_o.}$$

V_o	V_{in}
$+V_{sat}$	$< -\left(\frac{R_2}{R_1}\right) V_{sat}$ to switch V_o from $+V_{sat}$ to $-V_{sat}$
$-V_{sat}$	$> \left(\frac{R_2}{R_1}\right) V_{sat}$ to switch V_o from $-V_{sat}$ to $+V_{sat}$.



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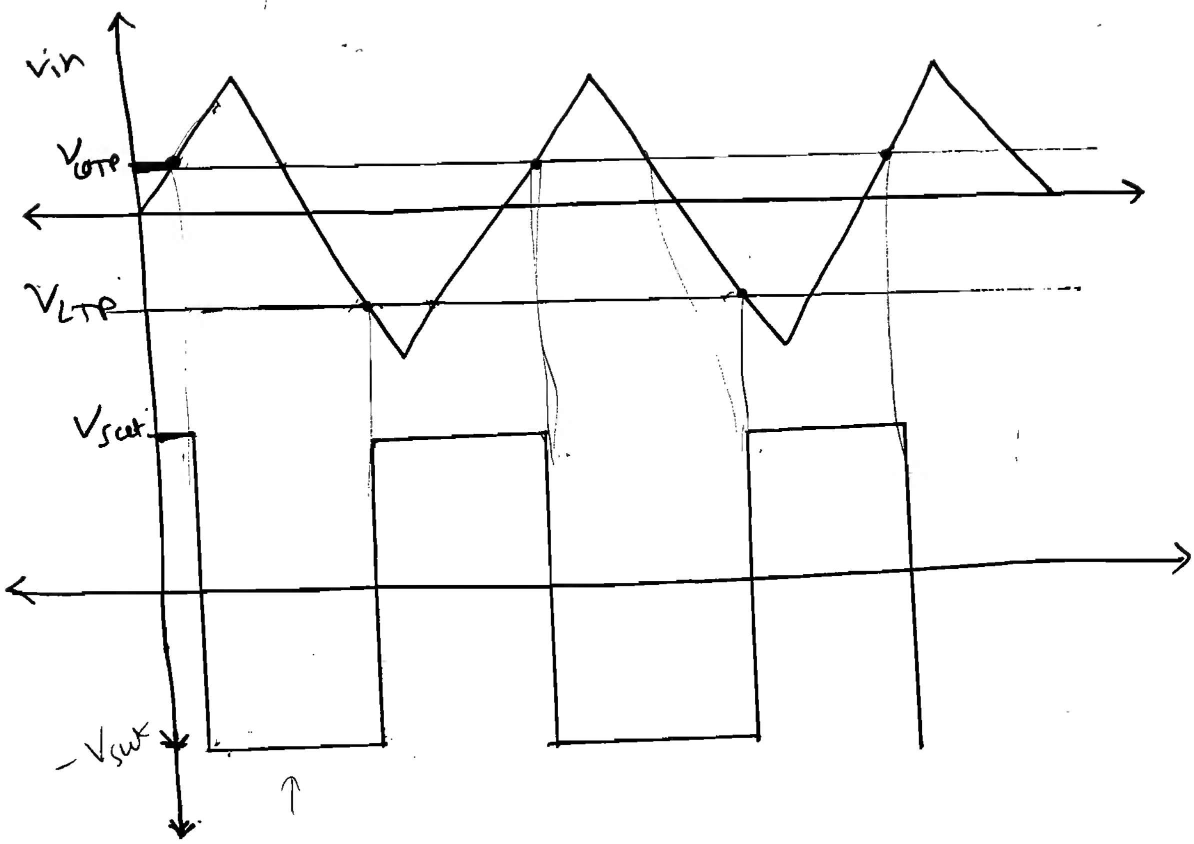
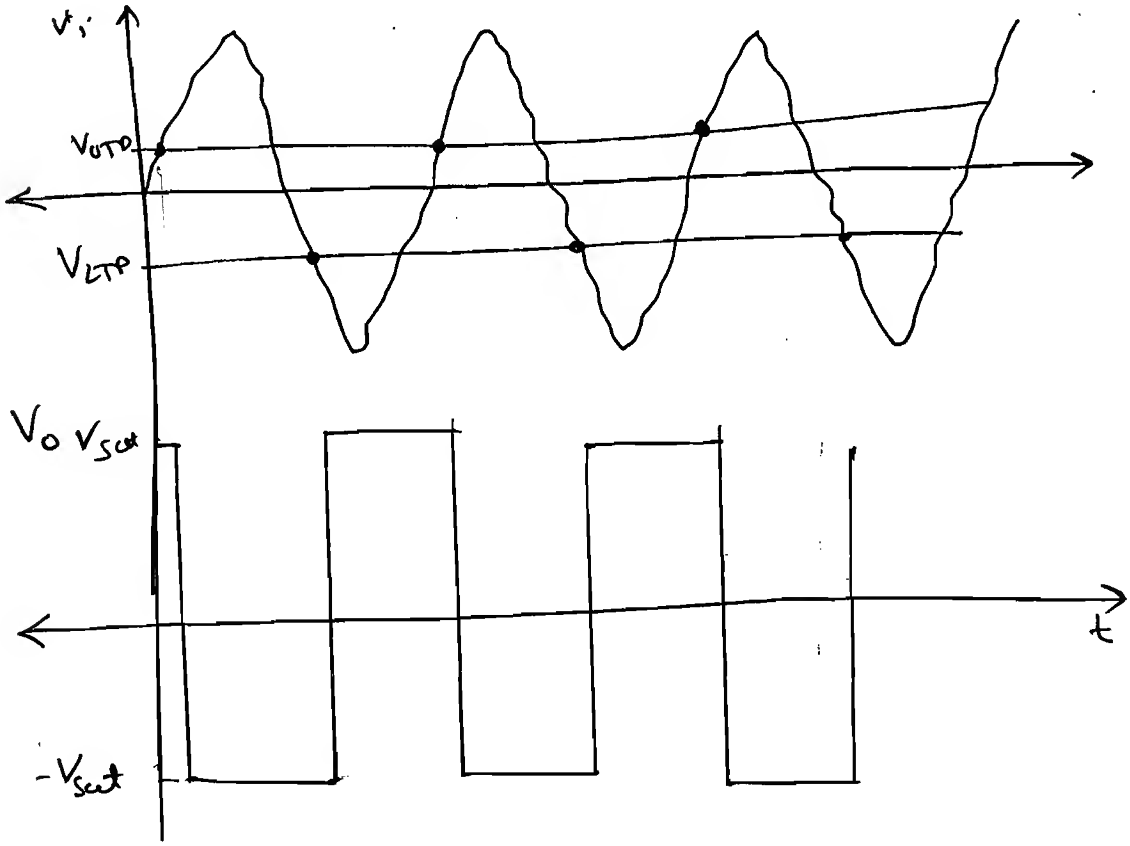
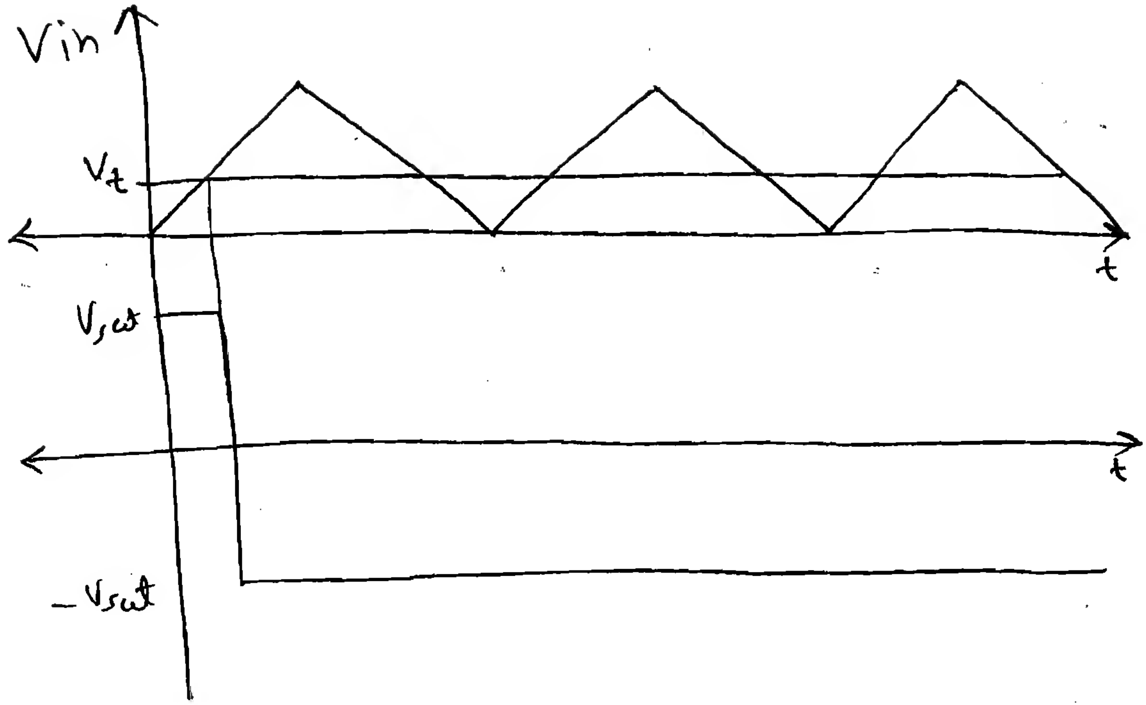

vin
V_{UTP}
V_{LTP}
V_{sat}
$-V_{sat}$

*

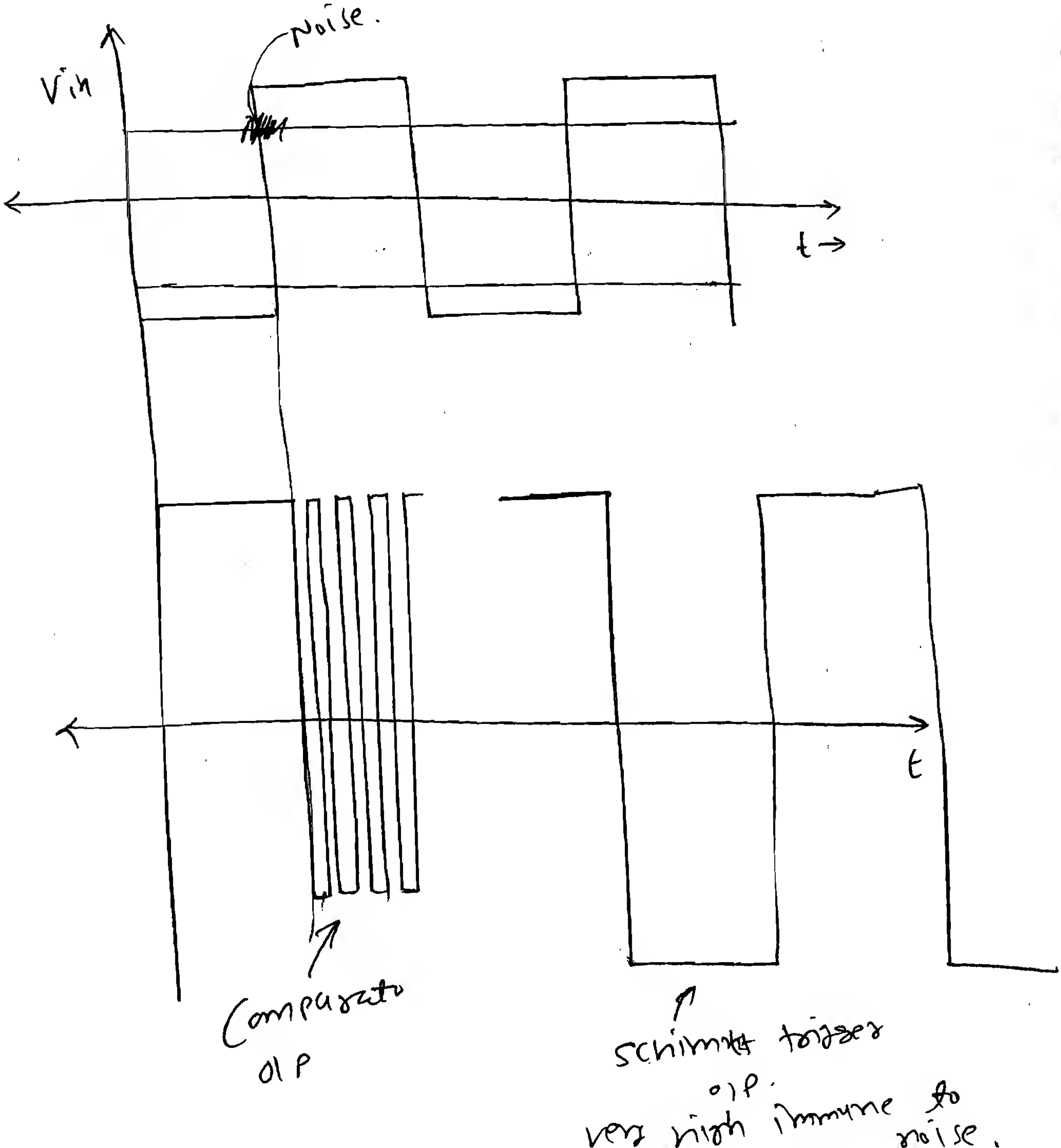

v_i
V_{UTP}
V_{LTP}
V_o V_{sat}
$-V_{sat}$
t

*



Vin
Vt
t
Vsat
t
-Vsat

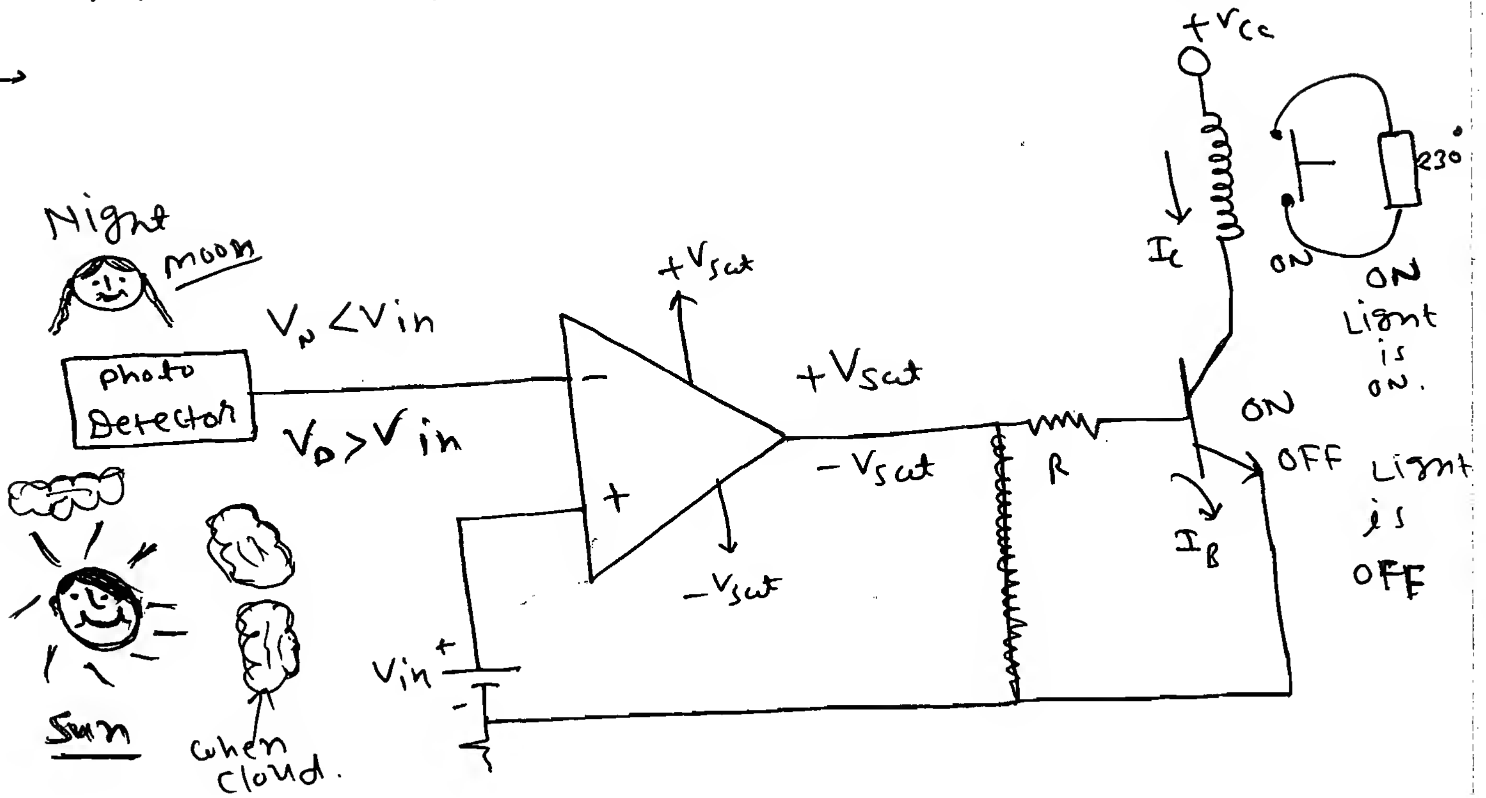
*



Noise.
Vin
t →
t
Comparator
O/P
Schmitt trigger
O/P.
very high immune to noise.

* One more application of Schmitt trigger:

→



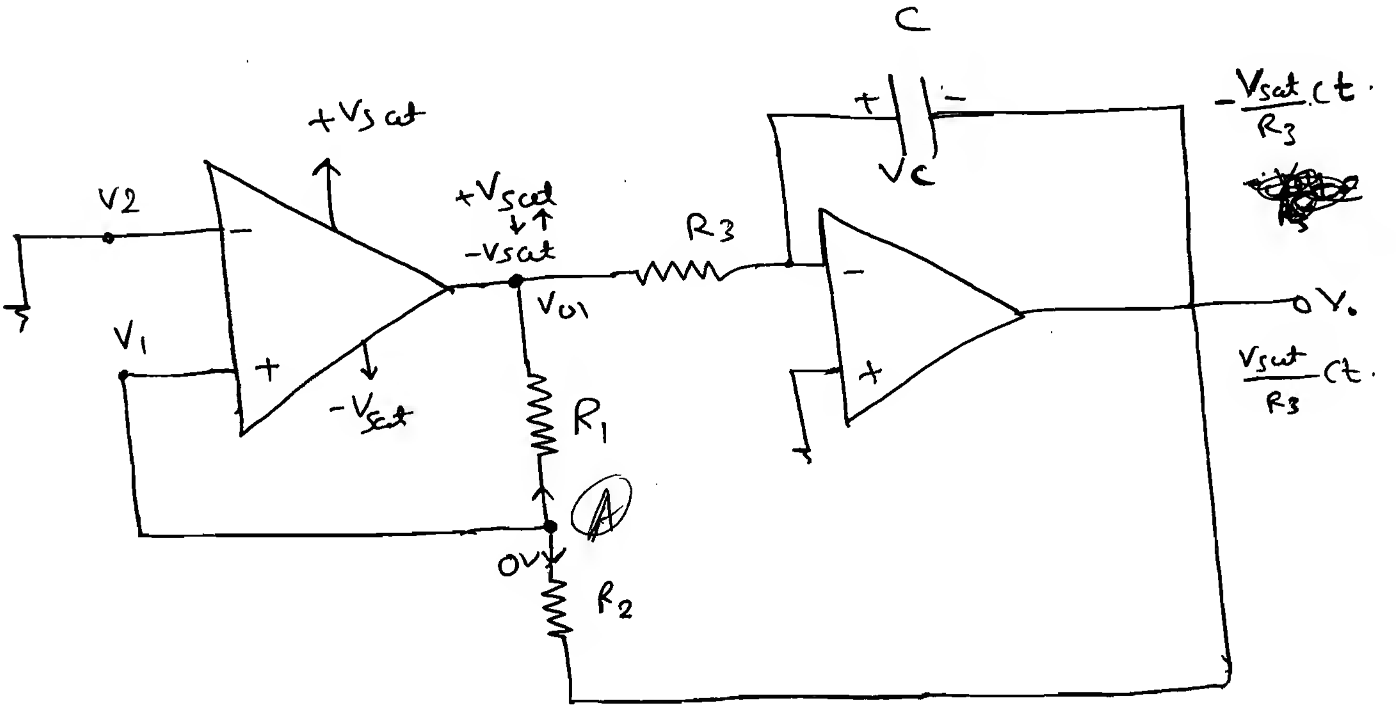
But

→ when Cloud come $V_N < V_{in} < V_D$.

$V_N = V_{UTP}$

$V_D = V_{LTP}$.

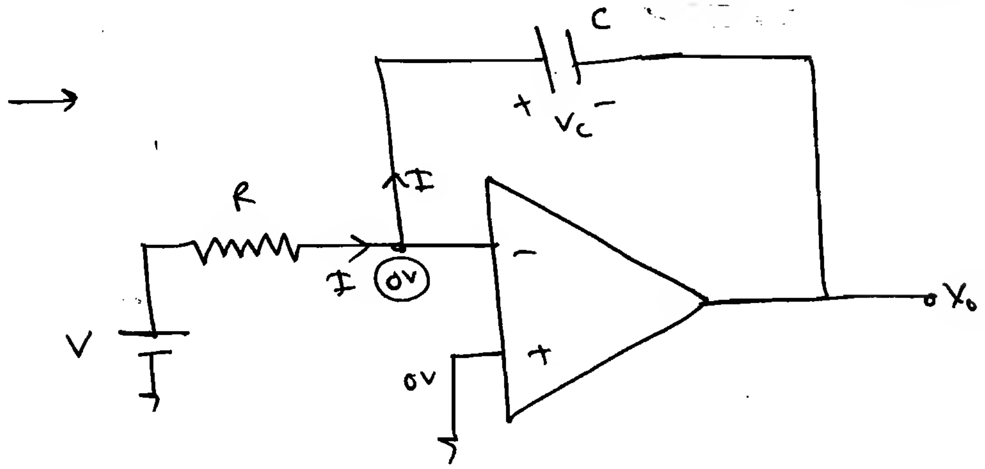
* Triangular wave generator:



$V_o < -\frac{R2}{R} V_{sat}$

$V_o > \frac{R2}{R} V_{sat}$

→



$\therefore \quad I = V/R.$

$$\therefore \quad V_c = \frac{1}{C}\int I\,dt$$

$$= \frac{1}{C}\int \frac{V}{R}\cdot dt$$

$$= \frac{V}{RC}\int dt$$

$$\therefore V_c = \left(\frac{V}{RC}\right)t.$$

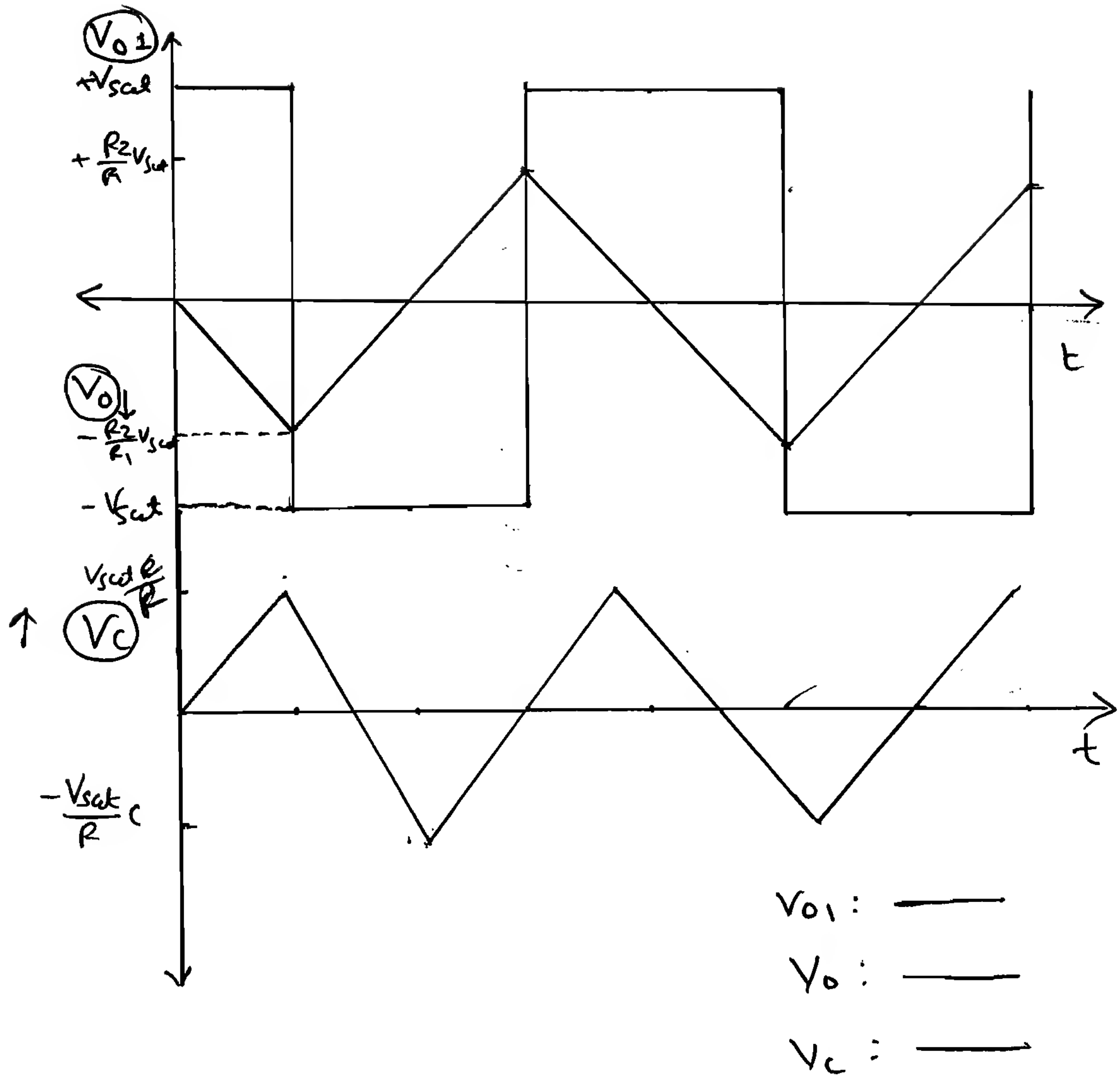
$$\therefore \quad 0 - V_0 = V_c.$$

$$\therefore \boxed{V_0 = -\left(\frac{V}{RC}\right)t.}$$

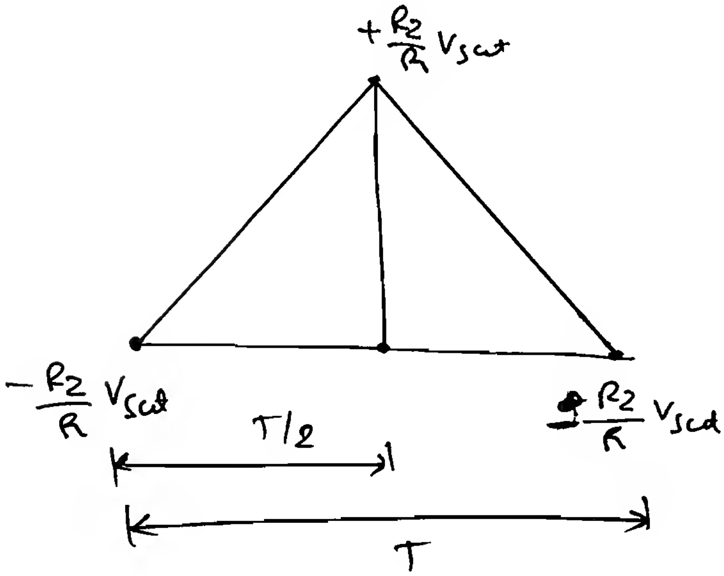
→ at node - A.

$$\therefore \quad \frac{0 - V_{01}}{R_1} + \frac{0 - V_0}{R_2} = 0.$$

$$\therefore \boxed{V_0 = -\left(\frac{R_2}{R_1}\right)V_{01}.}$$

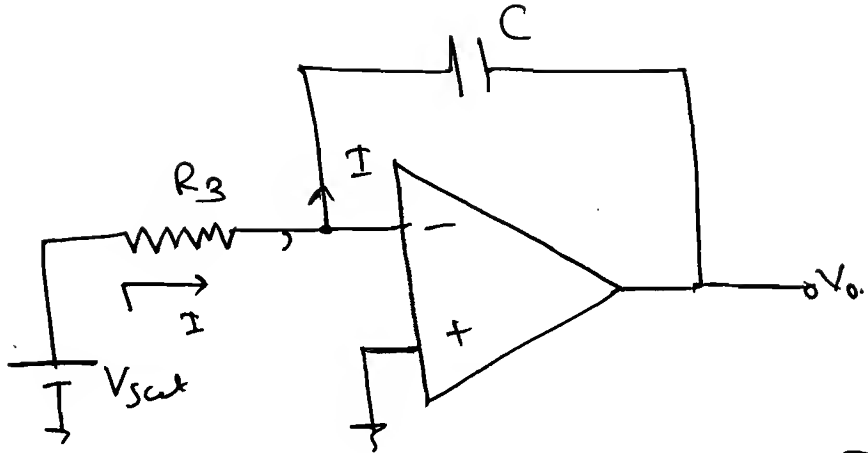


→



$$\therefore \quad V_c(t) = V_c(0) + \frac{1}{C}\int I\,dt.$$

$$\therefore \quad V_c(t) = -\frac{V_{sat}R_2}{R} + \frac{1}{C}\int I\,dt.$$



$$I = \frac{V_{sat}}{R_3}$$

$$\therefore \quad V_c = \frac{1}{C}\int I \, dt.$$

$$\therefore \quad V_c(t) = \frac{1}{C}\int \frac{V_{sat}}{R_3} \cdot dt$$

$$V_c(t) = \frac{V_{sat}}{R_3 C} \cdot t$$

$$\therefore \quad V_c(t) = -\frac{R_2}{R_1} V_{sat} + \frac{V_{sat}}{R_3 C} \cdot t.$$

but at $t = T/2$. $\quad V_c(t) = \frac{R_2}{R_1} V_{sat}$

$$\therefore \quad \frac{R_2}{R_1} V_{sat} = -\frac{R_2}{R_1} V_{sat} + \frac{V_{sat}}{R_3 C} \cdot (T/2).$$

$$\therefore \quad \frac{2 R_2}{R_1} \cancel{V_{sat}} = \frac{\cancel{V_{sat}}}{R_3 C} \cdot (T/2)$$

$$\therefore \quad \boxed{T = \frac{4 R_2 R_3 C}{R_1}}$$

$$\therefore \quad \boxed{f = \frac{R_1}{4 R_2 R_3 C}}$$

If $\quad R_1 = R_2 = R_3 = R$

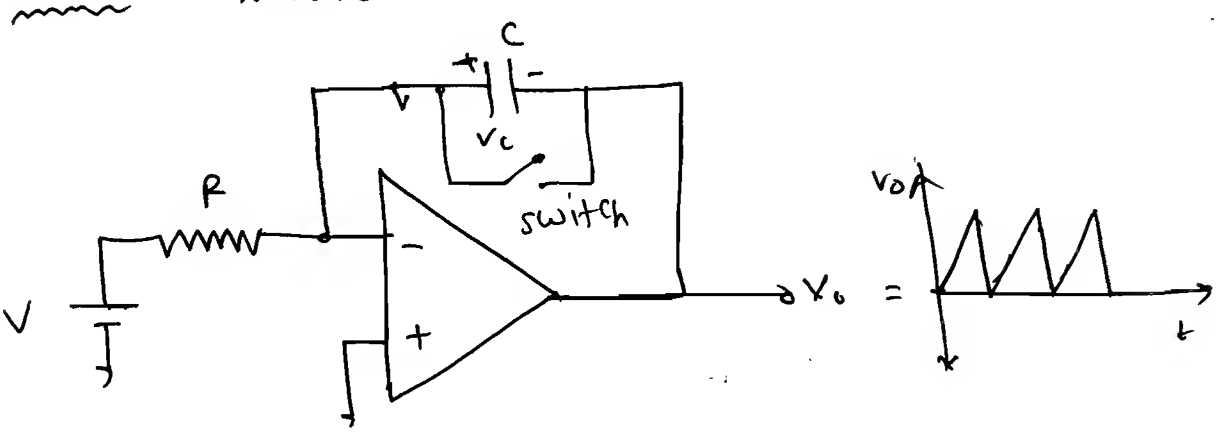
$$\therefore \quad \boxed{f = \frac{R}{4RC}}$$

* Sweep circuits:

→ There are mainly two way to generate sweep (sawtooth) waveform:

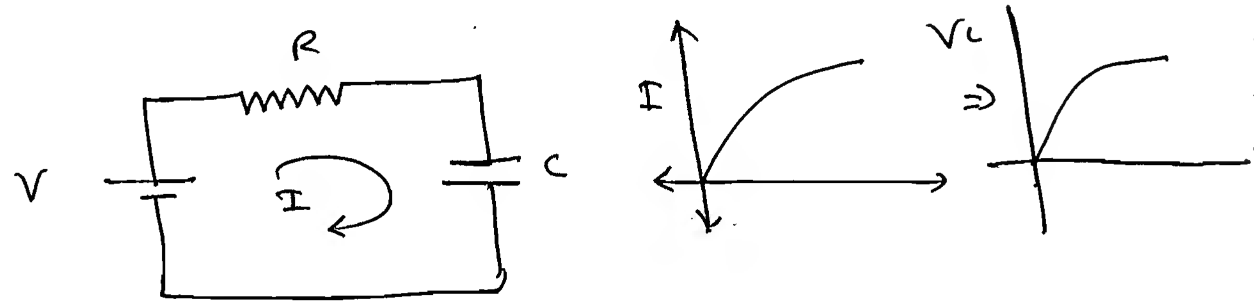
1. Miller sweep circuit
2. Boot strap sweep.

① Miller sweep circuit:



② (Boot strap sweep):

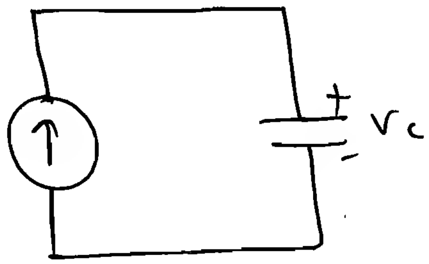
→ If current through a capacitor is exponential then capacitor charge in exponential fashion.



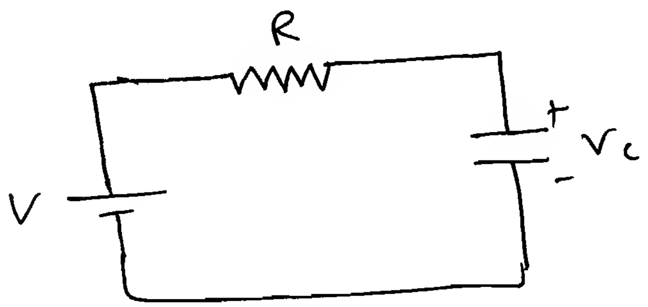
⇒ ~~I_c~~ ~~$\frac{1}{C}\int$~~

$$V_c = \frac{1}{C}\int I_c dt.$$

→ if V_c has to be linear I has to be constant



→



KVL_1 $\quad -V + IR + V_c = 0.$

$\therefore$ we has to get I = constant = V/R

To do so V_c should be vanishes.

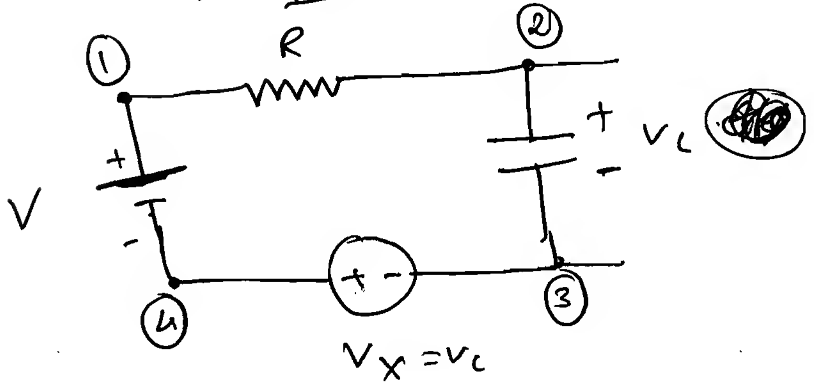
By changing KVL,

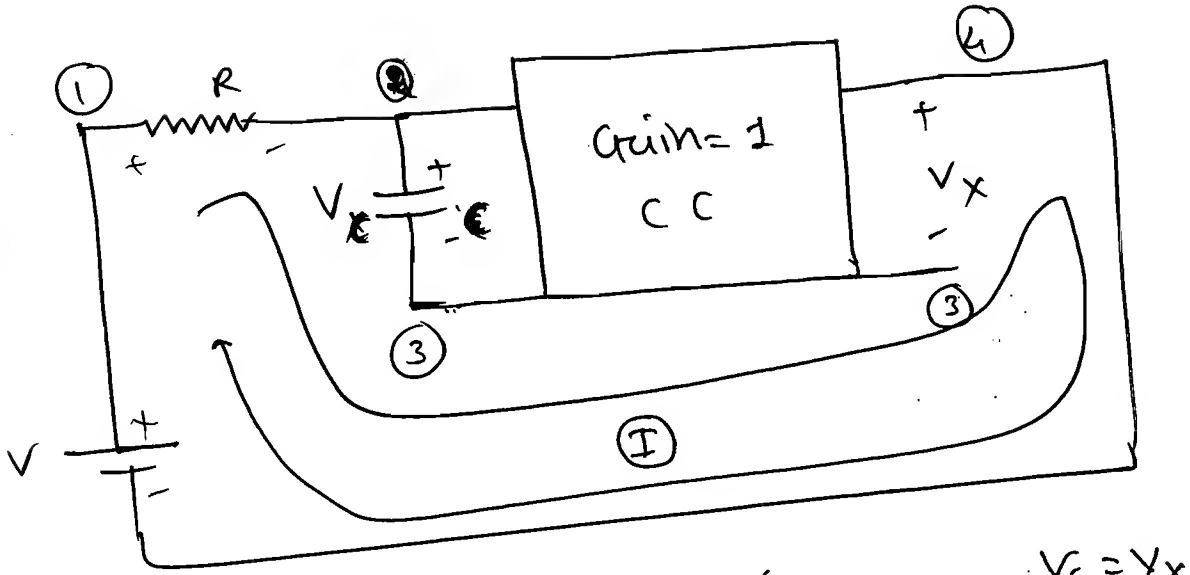
$\therefore -V + IR + V_c - \underbrace{V_c}_{V_x} = 0.$

$\therefore -V + IR + V_c - V_x = 0.$

$\boxed{V_x = V_c} \Rightarrow \frac{V_c}{V_x} = 1.$

$\therefore \boxed{I = V/R}$



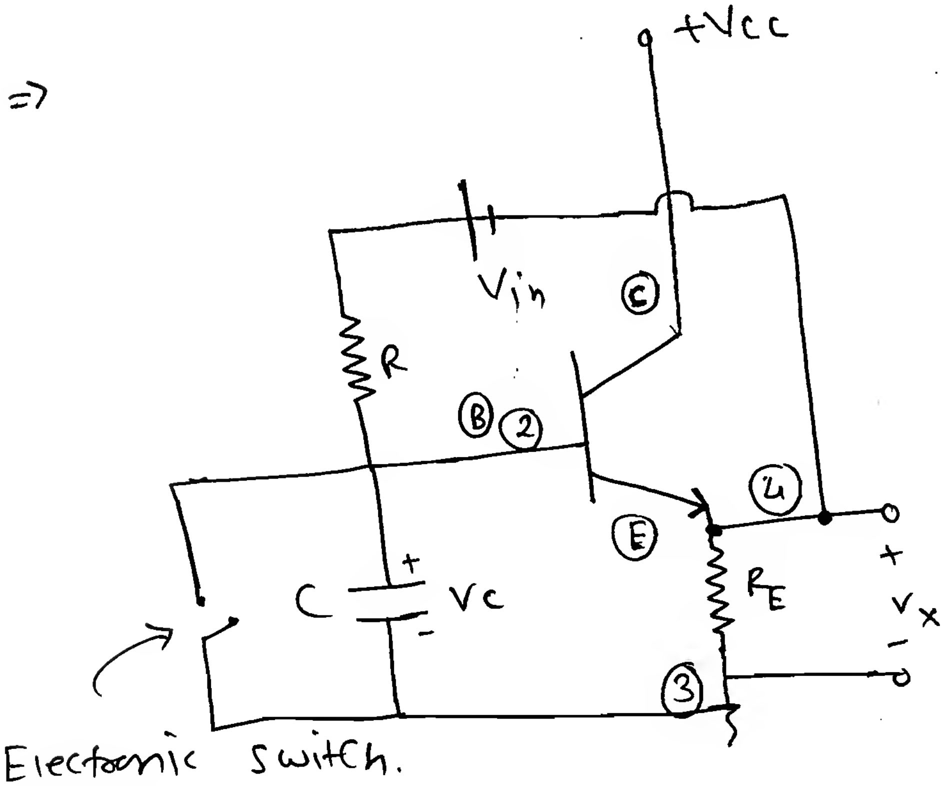


$$-V + IR + V_c - V_x = 0 \qquad V_c = V_x$$

$\therefore$

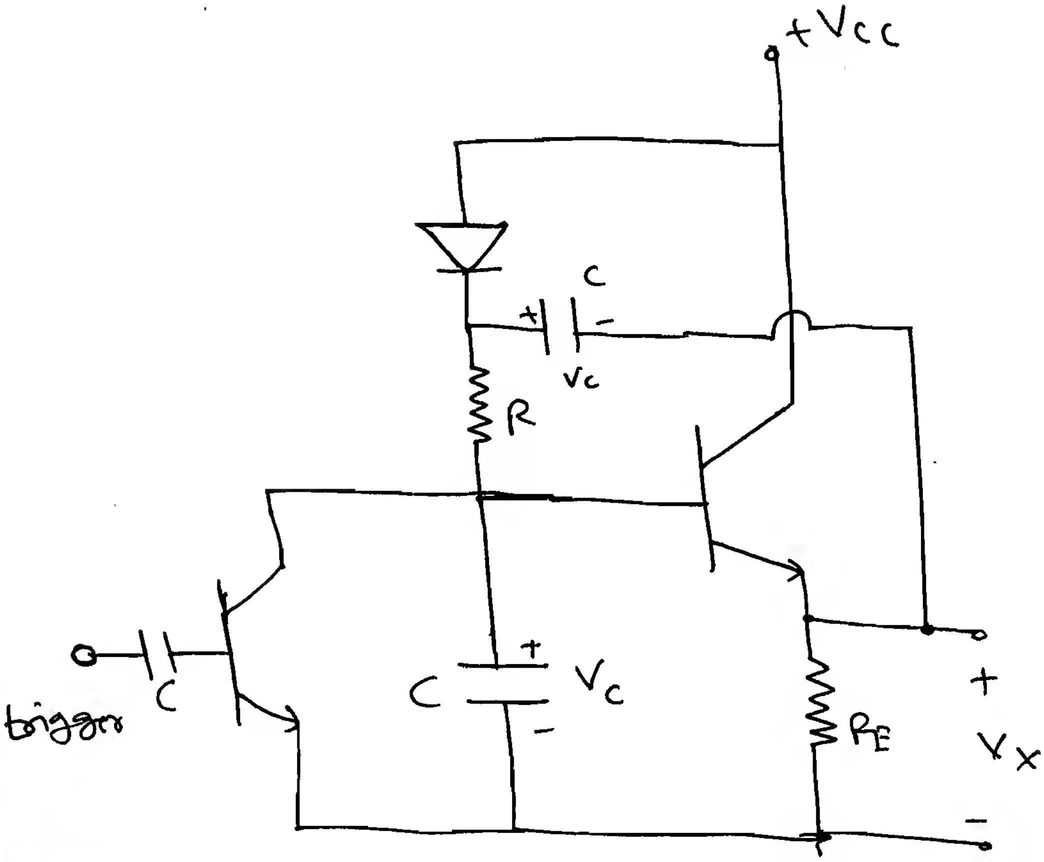
$\Rightarrow \boxed{I = V/R}$

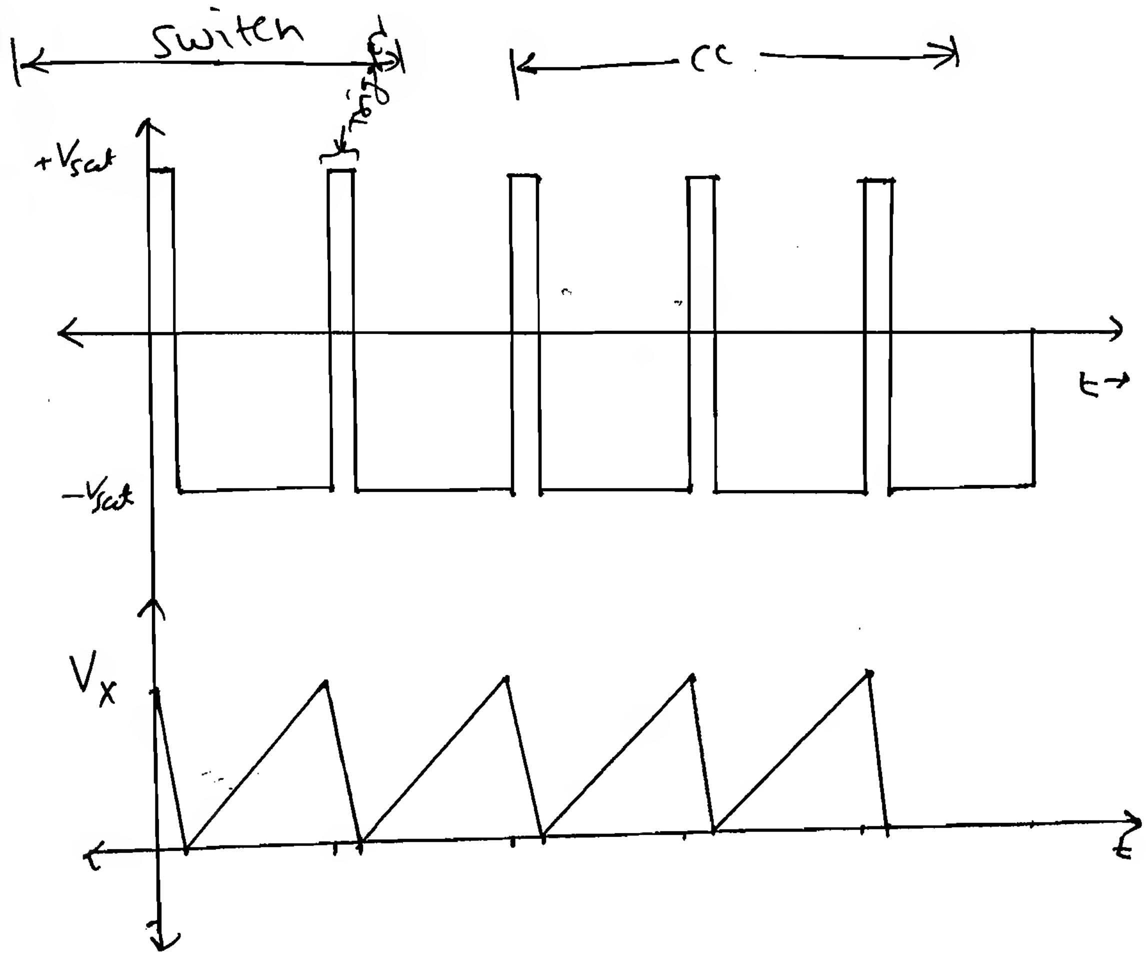
$\Rightarrow$



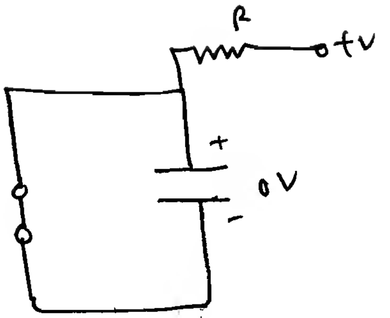
<u>NOTE:</u> Instead of two dc supply Vcc and Vin we can replace voltage same Vin with a capacitor. The charging time constant is far less as compared with discharging. Hence charge the

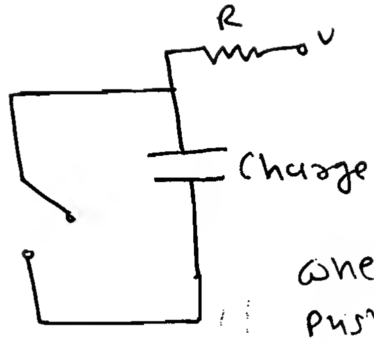
capacitor through a Diode.



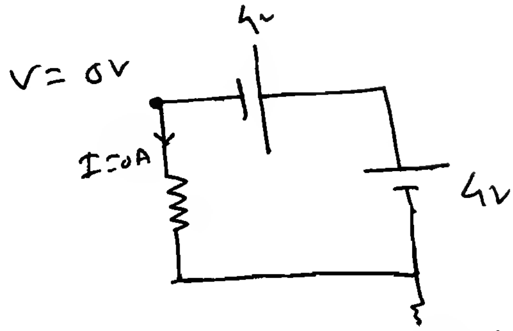


①



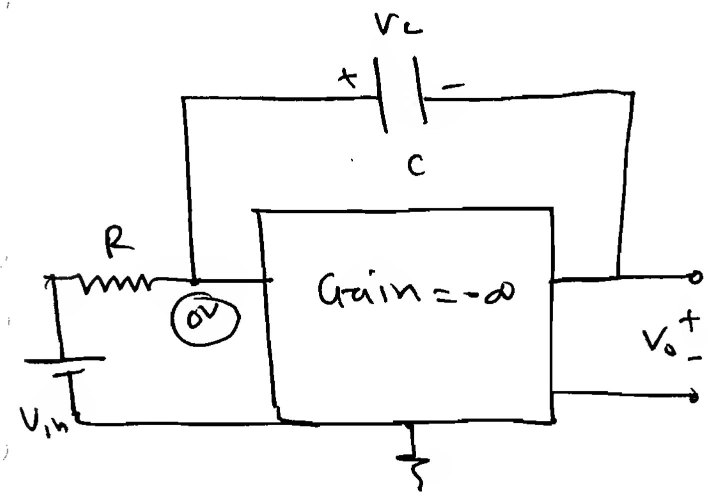


whenever we push trigger (or) push switch. capacitor discharge through BJT that particular time.

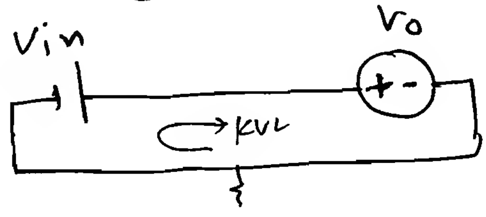


(nullator ckt) (V=0, I=0).

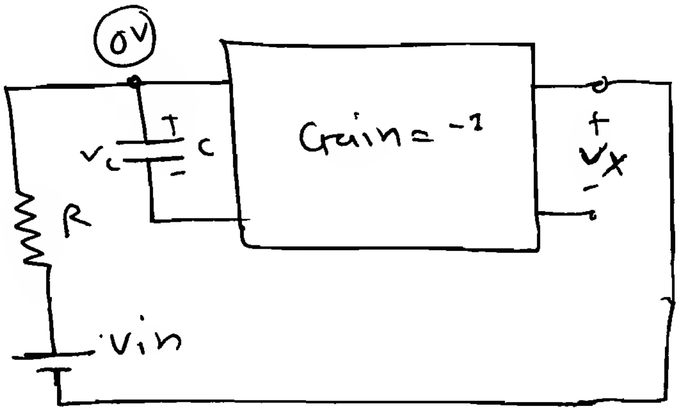
Miller sweep	Boot strap sweep



1. Amp gain is very high.
2. Neg. feedback
3. $I = V/R$
4. $V_C = \left(\frac{V}{RC}\right)t$



$V_{in} - V_o = 0$
Neg. f/B

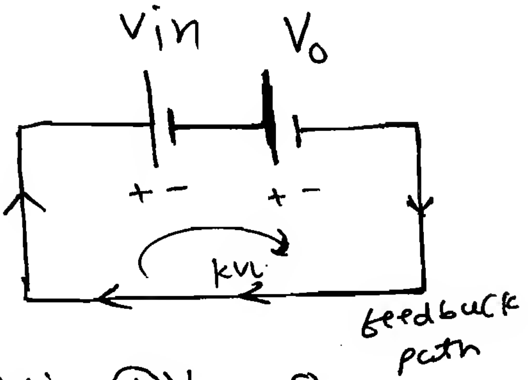


1. Amp gain = 1
2. Pos. feedback = 1.
3. $I = V/R$
4. $V_C = \left(\frac{V}{RC}\right)t$

$V_{in} + V_o = 0$
pos. f/B.

* Techniques for identifying type of feedback:

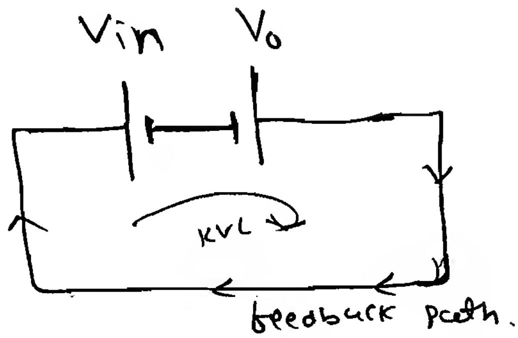
①



$\therefore V_{in} + V_o = 0$

↓ Positive feedback

②



$V_{in} - V_o = 0$

↓ negative feedback.

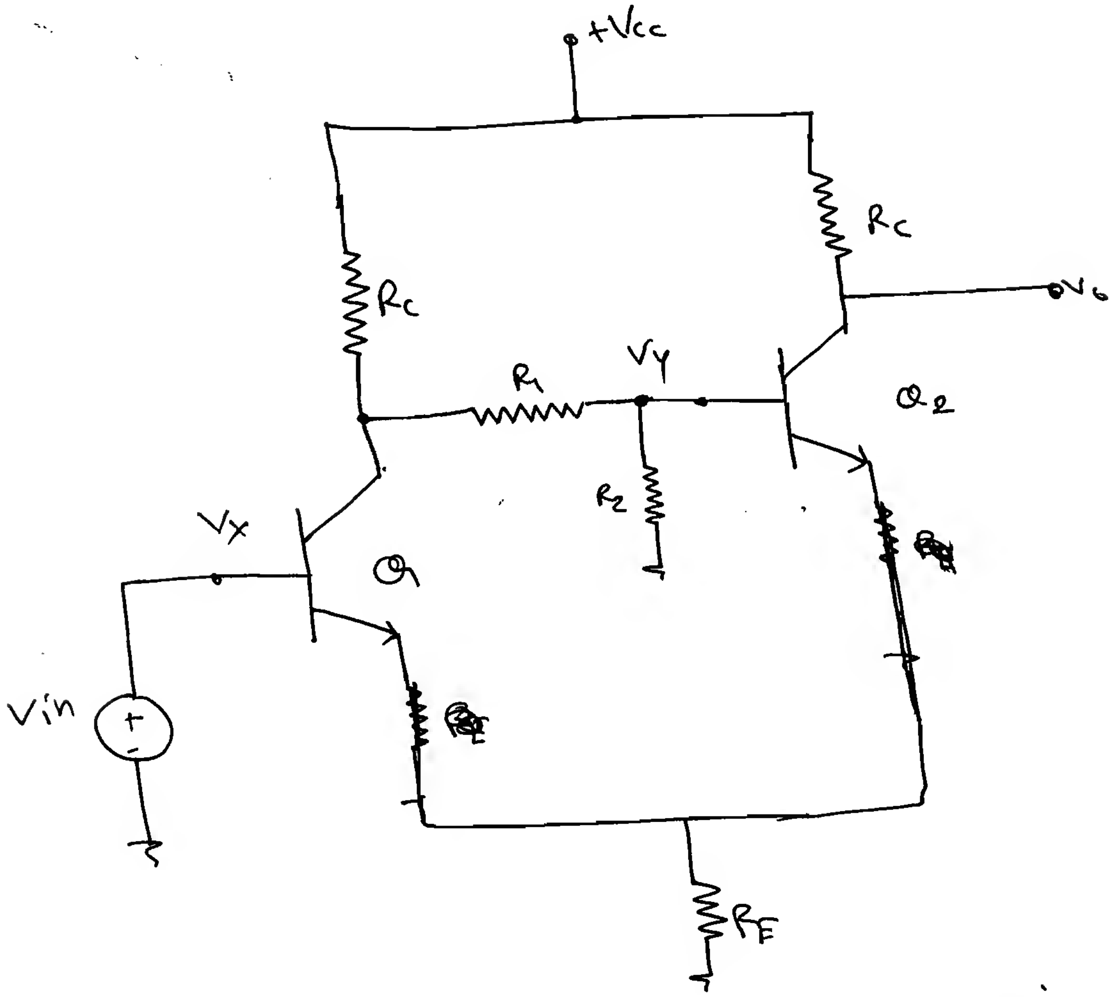
→ If -ve/(or) +ve terminal of o/p is connected to the +ve/(or) -ve terminal of i/p then it is positive feedback

-ve → +ve
+ve → -ve

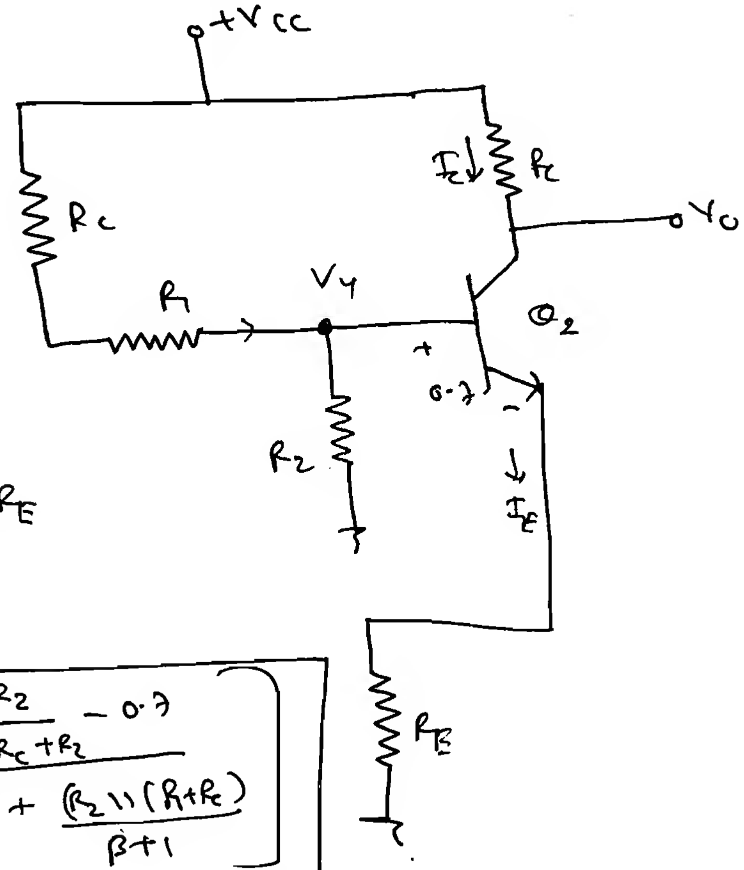
→ If +ve/-ve terminal of o/p is connected to the +ve/-ve terminal of i/p then it is called negative feedback.

-ve → -ve
+ve → +ve.

☆ Schmitt Trigger using BJT:



case-1: Vin=0 ⇒ Q1 is OFF and Q2 is on.



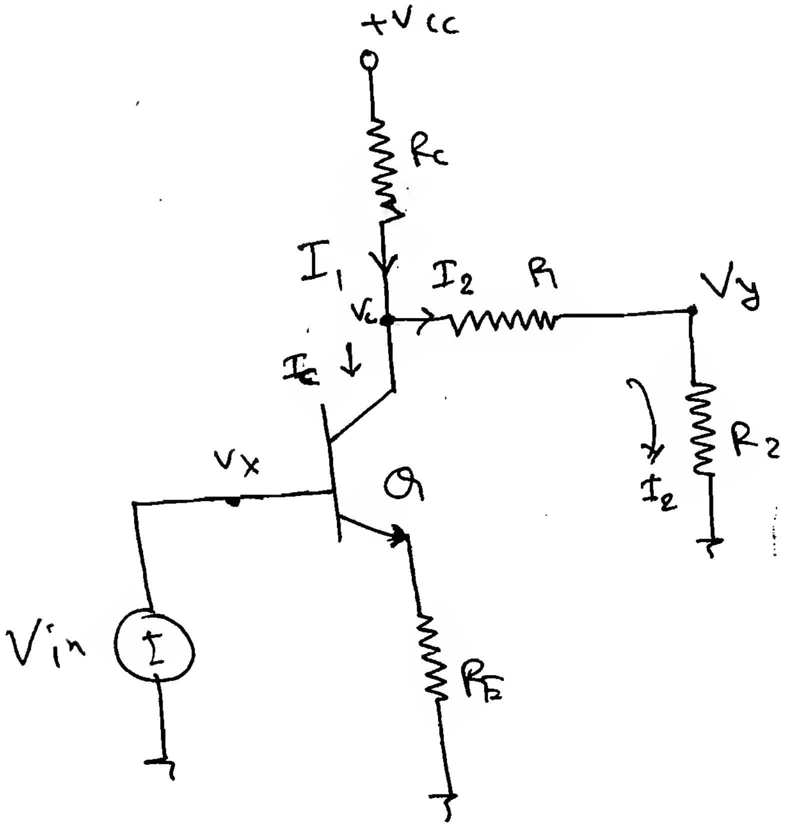
$$V_y = 0.7 + I_E R_E$$

$$I_{E_1} \approx I_1$$

$$\therefore \boxed{V_y = 0.7 + R_E \left[\frac{\frac{V_{cc} R_2}{R_1 + R_c + R_2} - 0.7}{R_E + \frac{R_2 \| (R_1 + R_c)}{\beta + 1}} \right]}$$

→ $V_{in} > V_y$ then Q_1 moves from OFF states to on state.

case - 2 : $Q_1 = ON$, $Q_2 = OFF$



$V_x = V_y$.

$\therefore I_1 = \dfrac{V_{cc} - V_c}{R_c}$.

$\therefore 0.7 + I_E R_E = V_y$.

$\therefore I_1 = \dfrac{V_{cc} - mV_y}{R_c}$.

$\therefore V_y = \dfrac{R_2}{R_1 + R_2} V_c$.

$\therefore I_2 = \dfrac{V_y}{R_2}$.

$V_c = \dfrac{R_1 + R_2}{R_2} \cdot V_y$.

$m = \dfrac{R_1 + R_2}{R_2}$.

$\therefore V_c = mV_y$.

$\therefore I_E \approx I_{c_1}$

$0.7 + I_{c_1} R_E = V_y$.

$\therefore 0.7 + (I_1 - I_2) R_E = V_y$.

$$\therefore \quad 0.7 + R_E\left(\frac{V_{cc} - mV_y}{R_c} - \frac{V_y}{R_2}\right) = \cancel{0}\, V_y.$$

$$\therefore \quad 0.7 + \frac{R_E V_{cc}}{R_c} = \left(1 + \frac{mR_E}{R_c} + \frac{R_E}{R_2}\right) V_y.$$

$$\therefore \quad \boxed{V_y = \frac{0.7 + \frac{R_E}{R_c} V_{cc}}{1 + m\frac{R_E}{R_c} + \frac{R_E}{R_2}}}.$$

→ $V_{in} < V_y$ to switch ~~Q~~ from ON state to OFF.

$$\boxed{|HW| = V_{UTP} - V_{LTP}.}$$

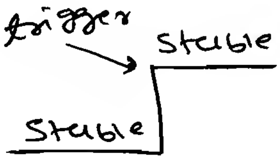
☆ Multivibrators :

29/07/2013

→ It is the regenerative circuit where transistor either work in cut off or Saturation and the op-Amp at the saturation limit.

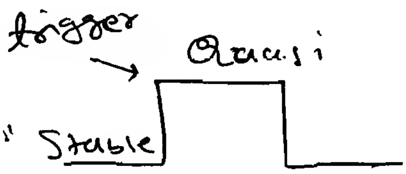
→ Based on the o/p state they are classified as:

1) Bistable Multi:



→ 2 Stable State
→ Binary F/F
→ eccless Jordan

2) Monostable Multi:



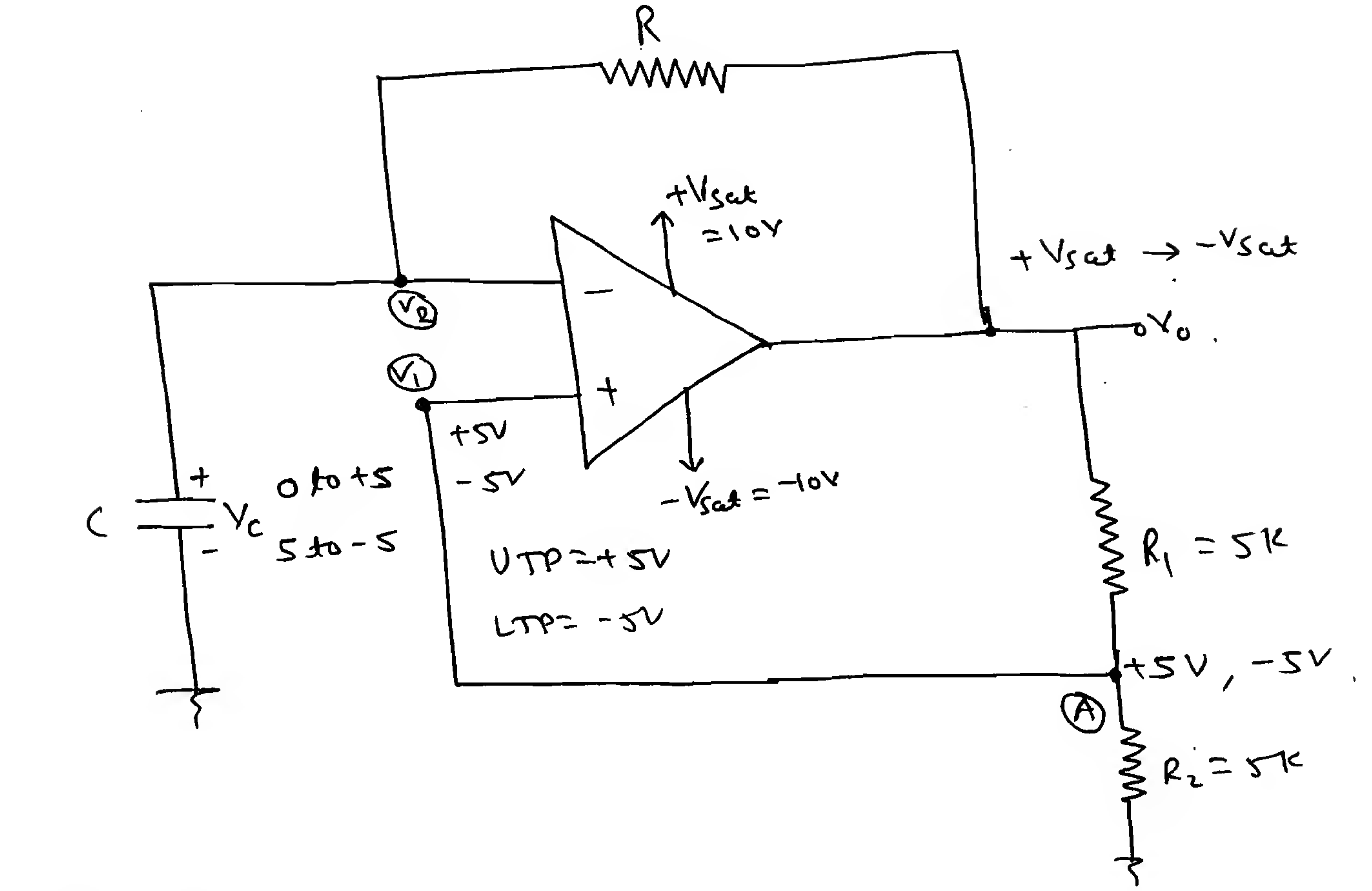
→ 1 - Stable State
→ 1- Quasi state
→ one shot
→ pulse generator.

3) Astable multi:

[No trigger required]

→ Free running
→ Square wave generator.

* Astable Multivibrator:



Operation:

→ Let, assume initialy o/p of op-Amp is Vsat. for simplicity take $R_1 = 5K$, $R_2 = 5K$. and Vsat $= 10V$.

→ Now, By voltage divider voltage at $V_1 = +5V$. fixed.

→ Now, As $V_o = +V_{sat} = +10$. capacitor C start to charge and V_2 increase from ~~to~~ 0 to +Vsat $= 10V$. But as soon as $V_2 \geq 5$, $V_2 > V_1$ and V_o switch from +Vsat to -Vsat. i.e when V_o switch from +Vsat to -Vsat.

$V_2 > \frac{R_2}{R_1} \cdot V_{sat}$ ⇒ V_o switch from +Vsat to -Vsat.

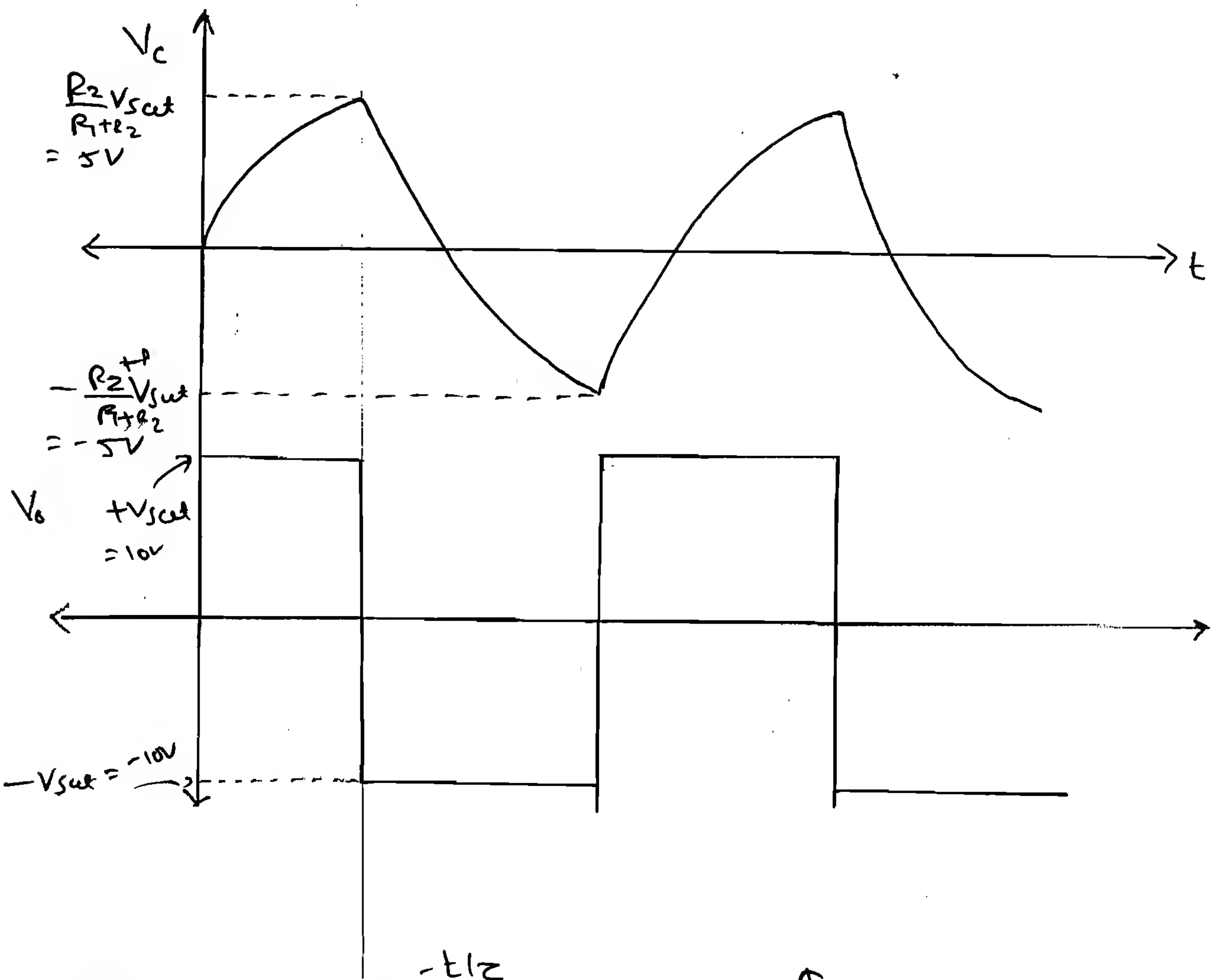
⇒ Now, as $V_o = -V_{sat} = -10V$. ⇒ Voltage at $V_1 = -5V$ (By voltage divider $\frac{-R_2}{R_1} \cdot V_{sat}$). and capacitor

Charges from +5 to $-V_{sat}$. But as $V_2 > -5$

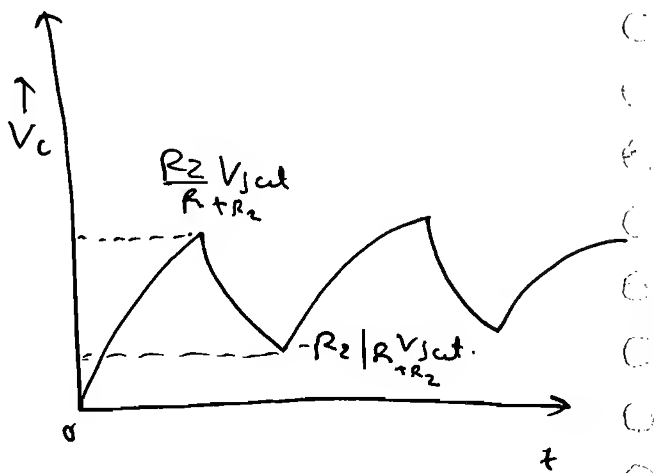
i.e. when $V_2 > -\frac{R_2}{R_1+R_2} V_{sat}$ then $V_2 < V_1$

and O/P switch from $-V_{sat}$ to $+V_{sat}$.

and cycle repeat.



$\rightarrow V_c(t) = A + Be^{-t/\tau}$



$\therefore$ at $t=0$

$V_c(0) = A + B$.

at $t = \infty$

$\therefore \boxed{V_c(\infty) = A}$

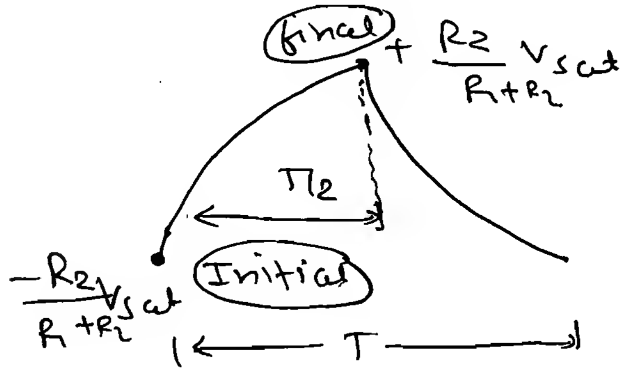
$B = (A+B) - A$.

$\therefore B = V_c(0) - V_c(\infty)$.

$\therefore V_c(t) = [V_c(0) - V_c(\infty)]e^{-t/\tau} + V_c(\infty)$.

$$\Rightarrow \boxed{V_c(t) = [V_c(0) - V_c(\infty)]\, e^{-t/\tau} + V_c(\infty).}$$

→



$$\Rightarrow \quad V_c(t) = [V_c(0) - V_c(\infty)] \cdot e^{-t/\tau} + V_c(\infty).$$

$$\therefore \quad V_c(t) = \left[-\frac{R_2}{R_1+R_2} V_{sat} - V_{sat}\right] \cdot e^{-t/\tau} + V_{sat}.$$

at $t = T/2$, $\quad v_c(t) = \frac{R_2}{R_1+R_2} V_{sat}.$

$$\therefore \quad \frac{R_2}{R_1+R_2} V_{sat} - V_{sat} = \left[-\frac{R_2 V_{sat}}{R_1+R_2} - V_{sat}\right] \cdot e^{-T/2\tau}.$$

$$\therefore \quad \frac{R_2}{R_1+R_2} - 1 = -\left[\frac{R_2}{R_1+R_2} + 1\right] \cdot e^{-T/RC\times 2}.$$

$(\because \tau = RC).$

$$\therefore \quad \frac{R_1}{\cancel{R_1+R_2}} = \frac{2R_2 + R_1}{\cancel{R_1+R_2}} \cdot e^{-T/2RC}$$

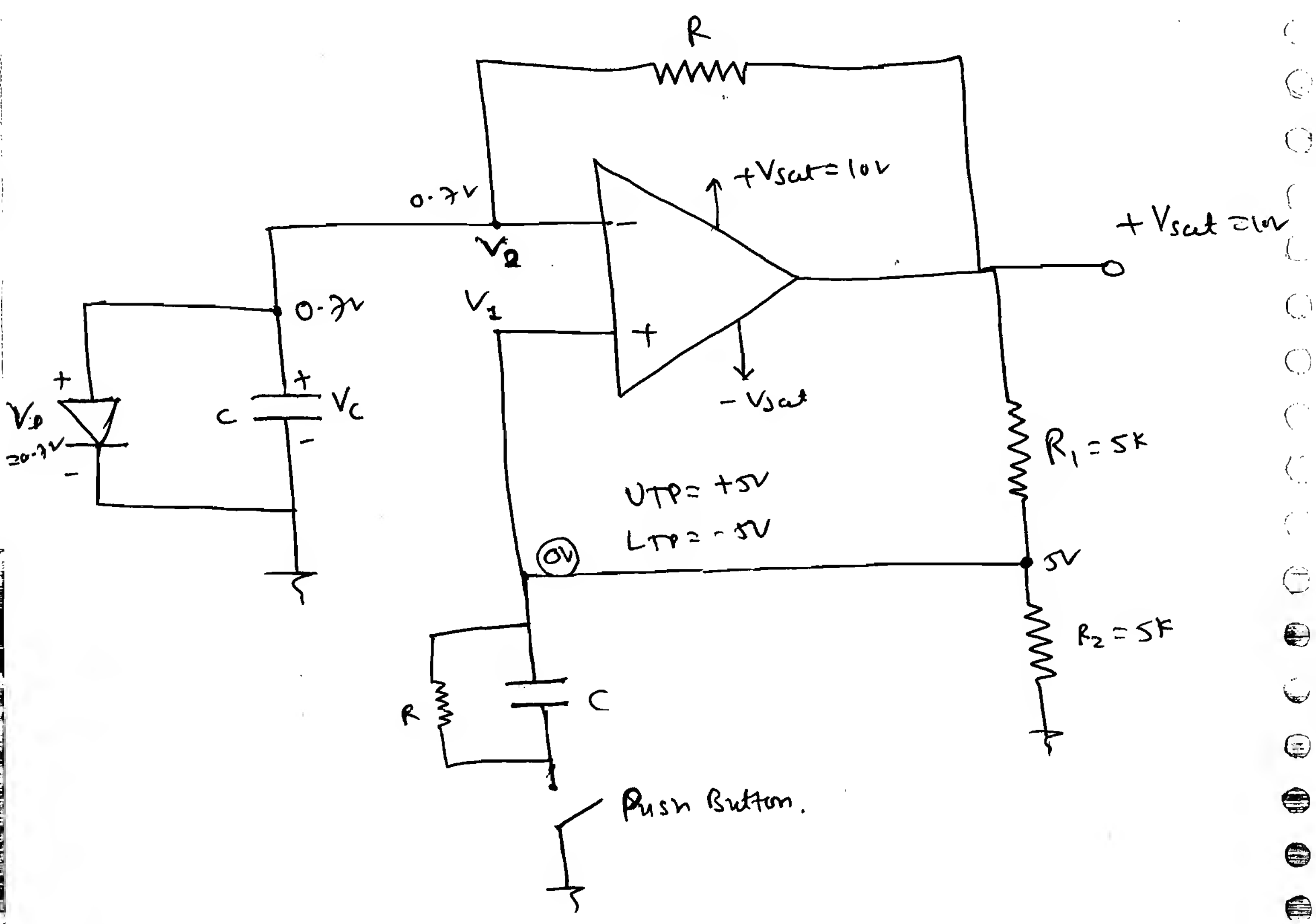
$$\therefore \quad e^{T/2RC} = \frac{2R_2 + R_1}{R_1}.$$

$$\therefore \quad \frac{T}{2RC} = \ln\left(1 + \frac{2R_2}{R_1}\right)$$

$$\therefore \quad T = 2RC \ln\left(1 + \frac{2R_2}{R_1}\right).$$

$$\therefore \quad \boxed{T = -2RC \ln\left[\frac{R_1}{R_1 + 2R_2}\right].}$$

☆ Monostable Multivibrator-



→ ~~Let~~ In order to understand operation of mono-stable multivibrator let's take one practical application.

→ Let, there is one coffeee machine. In that there is one push button. Now, when customers want to a cup of coffee they have to push that button. Once the cup will full with the coffee, machine will automatically stop to give more coffee. and after that coffee machin will come in its ~~on~~ initial state.

⇒ Now, another Customer come do same thing to get a cup of coffee.

⇒ For this application we use monostable multivibrator. we can get monostable multi from Astable multi by making two changes as shown in figure with red mark.

⇒ Now, assume machine is in its initial State. i.e. o/p at op-Amp $V_o = +V_{sat} = 10V$ therefore, Voltage at $V_1 = +5V$ (By voltage divider rule).

→ Now, As $V_o = +V_{sat} = 10V$. Diode D is F.B. and voltage at $V_2 = 0.7$ V.

⇒ Now, as $V_1 > V_2$ output stays $+V_{sat}$.

⇒ Now, one customer come and push the button to get a cup of coffee. For this purpose (or) function we put a switch across V_1 along with tanke circuite. i.e. we ~~connect~~ give a trigger.

⇒ ~~As~~ when customer press the button. Voltage at V_1 becomes 0V and $V_1 < V_2$ and output switch from $+V_{sat}$ to $-V_{sat}$. as $V_o = -V_{sat}$, $V_1 = -5V$. , Diode is off ~~and~~ (R.B.). and Capacitor Charge.

0.7 V to $-V_{sat}$ (-5V).

→ ~~when cup is full coffee~~

→ ~~when $V_2 >> V_1$ i.e. $V_2 >> -5$~~

→ when $V_2 < V_1$ i.e. $V_2 < -5$. ~~then~~

(cup is full with coffee) then $V_1 - V_2 > 0$

and output switch from $-V_{sat}$ to $+V_{sat}$.

and machine will come into its initial

state ~~and~~ stop to give more coffee.

→ As $V_0 = +V_{sat}$, $V_1 = +5V$ and $V_2 = V_C = 0.7V$

(∵ D is on).

→ Now, next customer will come and press

the button to get coffee and cycle repeate.

⇒ During understand the operation following

two ~~question~~ quetion will arise in our

~~mide~~. mind.

Q-① Why should we put a RC tank ckt

instead of giving direct ground?

Ans: Answer is simple.

→ If we give direct ground then

$V = 0 \Rightarrow R = 0$ and $I = V/R$ ~~=~~ $I = V/\cancel{0}$

$\Rightarrow I = \infty$. therefore, very large current will

flow. by given direct ground.

→ Therefor ~~cus~~ ~~bit~~ the customer ~~g~~ will get

fire instead of coffee (☺).

⇒ Now, we put RC tank circuit.

when $V_{sat} = +10V$, $V_1 = +5V$ and capacitor start charging. A when we push the push button then capacitor will ground and discharge through a resistor slowly. and no large current will flow. Now, we get coffee instead of fire. ☺.

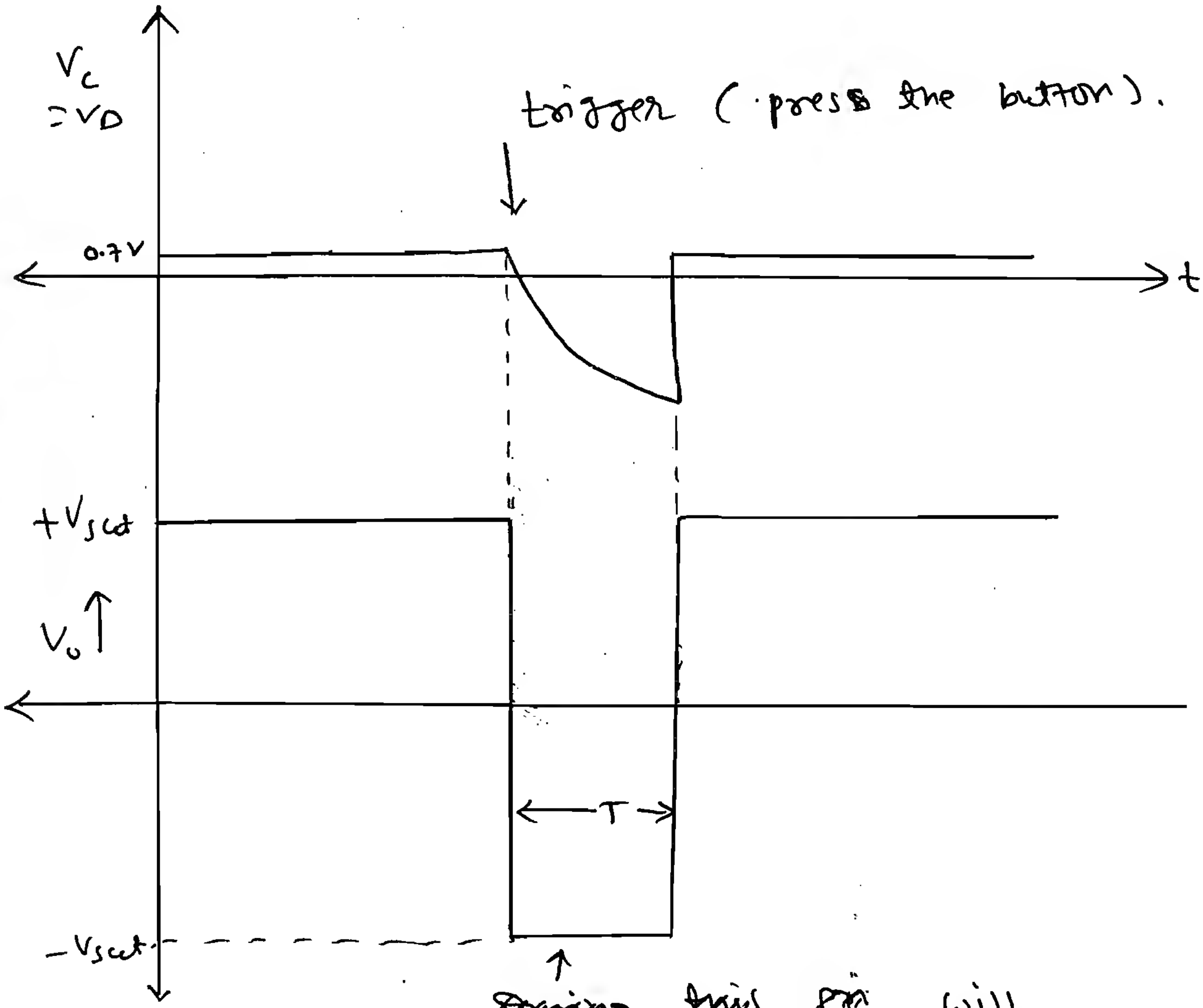
Q-2 Why should we place a Diode across a capacitor in non-inverting terminal?

Ans: Answer of this quetion is also very simple.

→ If we don't put a Diode then following thing can be done.

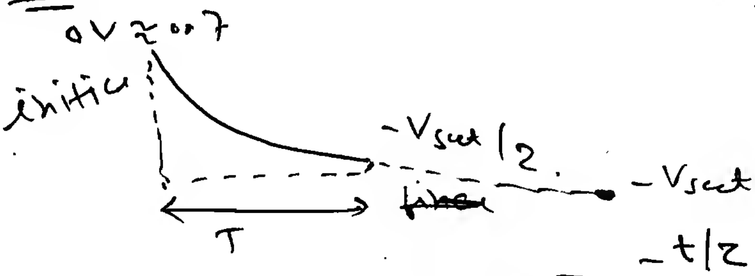
when $V_{sat} = +10V$. then capacitor charge from 0 to +5 V. one trigger is given. $V_1 = 0$ and $V_2 > V_1$ so, output switch from $+V_{sat}$ to $-V_{sat}$ and capacitor charge from +5 to -5. So, first customer will come and get coffee after that machine will stop. But as soon as V_2 exceed V_1 then $V_0 = +V_{sat}$ to $-V_{sat}$ and coffee will come again without pressing a button.

→ After one push, it becomes Square wave generator. So, coffee will come after ssuccesiive time. and second customer will be socked that coffee is comming for a short period of time and then stop and then again come. ~~The~~ He ~~thought~~ will think that is there any ghost?



~~During this pin~~ will
After T time cup ~~is~~ full
with coffee and machine stop.

Time period:



$$V_c(t) = [V_c(0) - V_c(\infty)]\, e^{-t/\tau} + V_c(\infty).$$

$\therefore \quad V_c(t) = [0.7 + V_{sat}] \cdot e^{-t/\tau} - V_{sat}.$

at $t = T$, $V_c(t) = -V_{sat}/2$.

$$\therefore \quad -\frac{V_{sat}}{2} = [0.7 + V_{sat}] \cdot e^{-T/\tau} - V_{sat}.$$

take $0.7 \approx 0$.

$\therefore$

$$\therefore \quad \frac{\cancel{V_{sat}}}{2} = \cancel{V_{sat}} \cdot e^{-T/\tau}.$$

$$\therefore \quad e^{T/\tau} = 2.$$

$$\therefore \quad \frac{T}{\tau} = \ln 2.$$

$$\therefore \quad T = RC \ln 2.$$

$$\therefore \quad \boxed{T = 0.69\,RC.}$$

$$\boxed{\text{Pulse width } T = 0.69\,RC.}$$

→ i.e. How much coffee will fall into the cup is decided by pulse width $T = 0.69RC$.

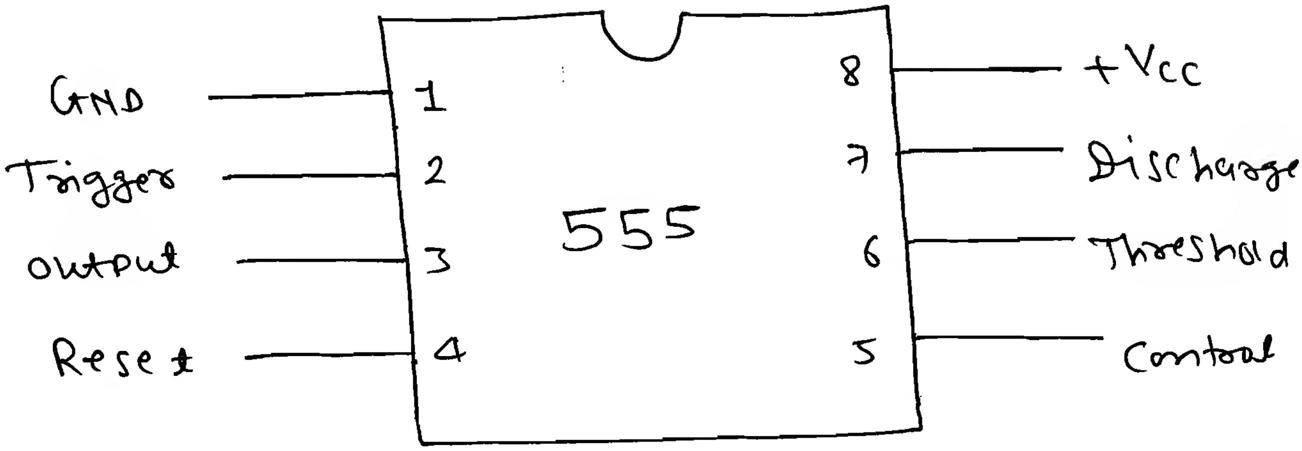
NOTE: OP-AMP

+ve terminal for Voltage summing.

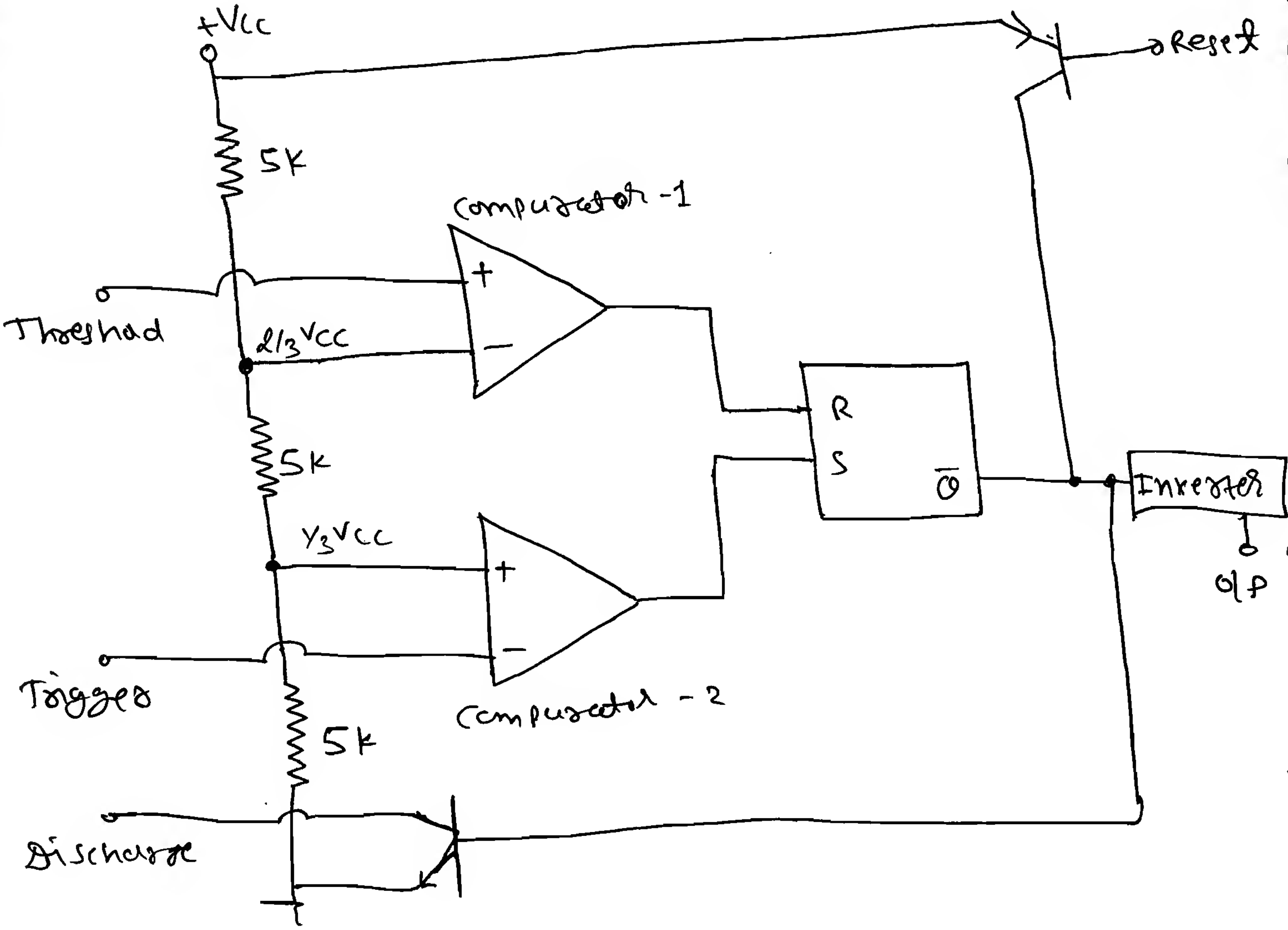
-ve terminal for current summing.

✯ Multivibrators Using 555 timer :-

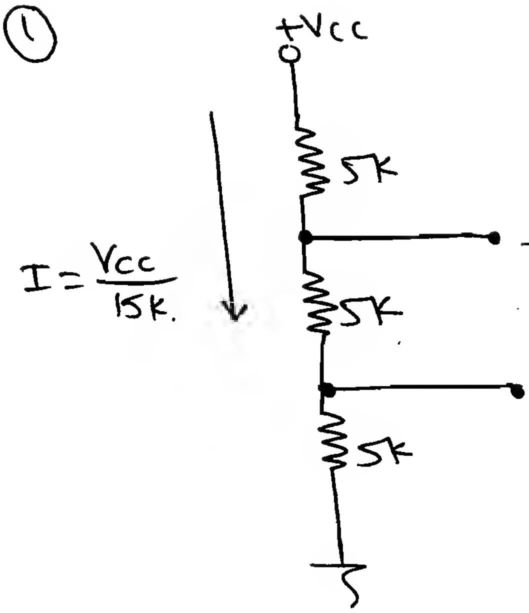
* 555 timer:



IC



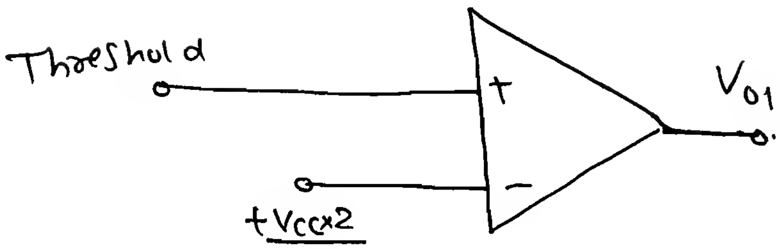
(1)



$$\frac{10K}{15K} V_{cc} = \frac{2}{3} V_{cc}.$$

$$\frac{5K}{15K} V_{cc} = \frac{1}{3} V_{cc}.$$

(2)

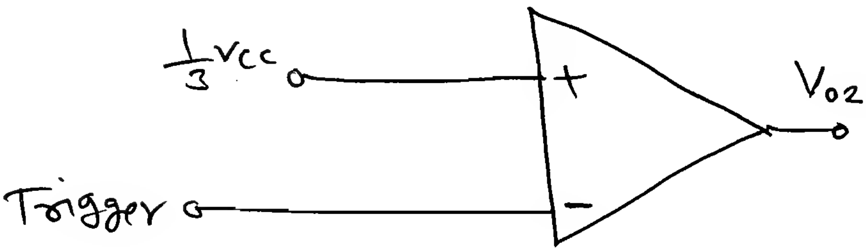


Threshold $> \frac{2}{3}$ => Logic '1'.

Threshold $< \frac{2}{3}$ => Logic '0'.

[Comparator − 1]

(3)

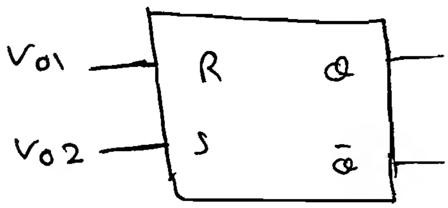


Trigger $< \frac{1}{3}V_{cc}$ => Logic '1'.

Trigger $> \frac{1}{3}V_{cc}$ => Logic '0'.

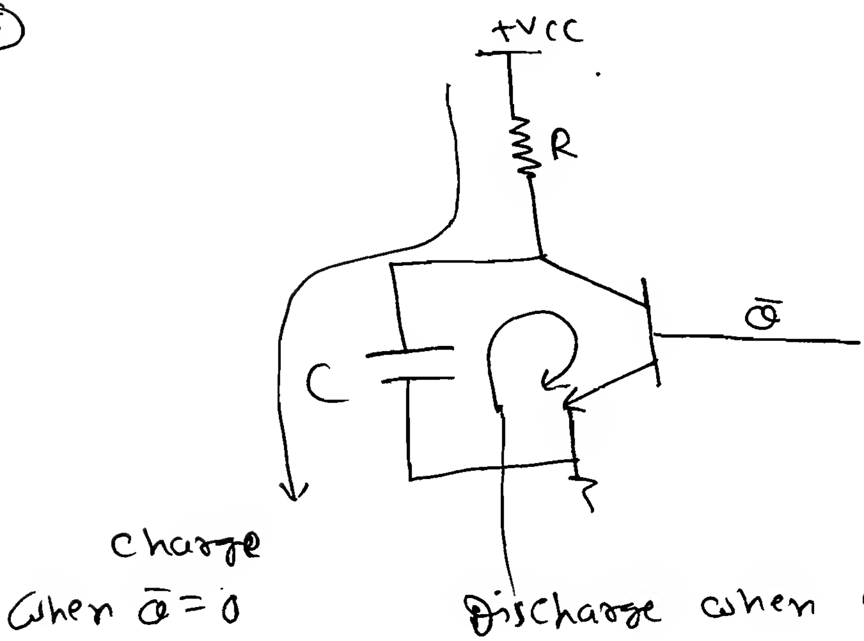
[Comparator − 2].

(4)



R	S	$\bar{Q}$	O/P = Q
0	0	previous	
0	1	0	1
1	0	1	0
1	1	Don't try.	

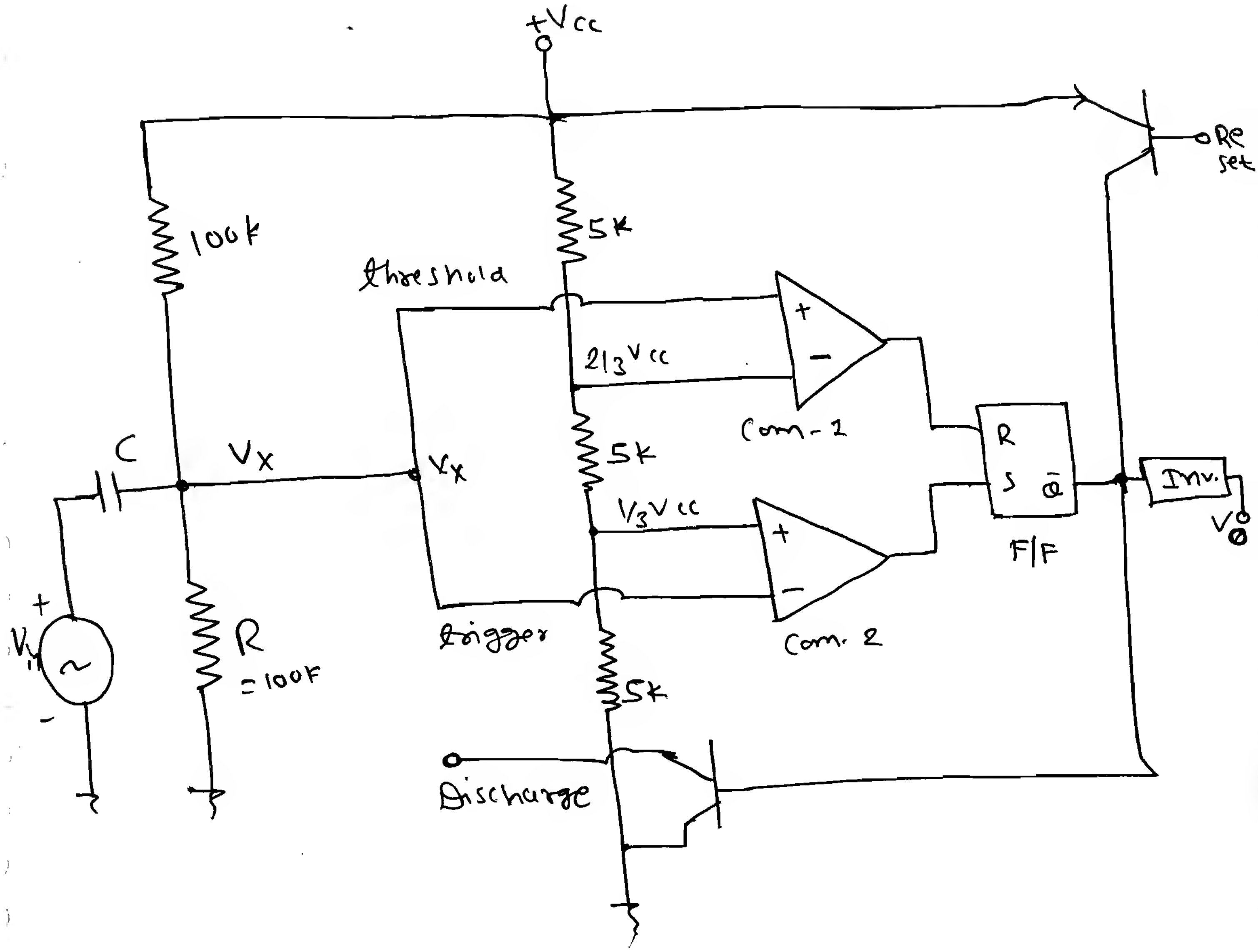
(5)



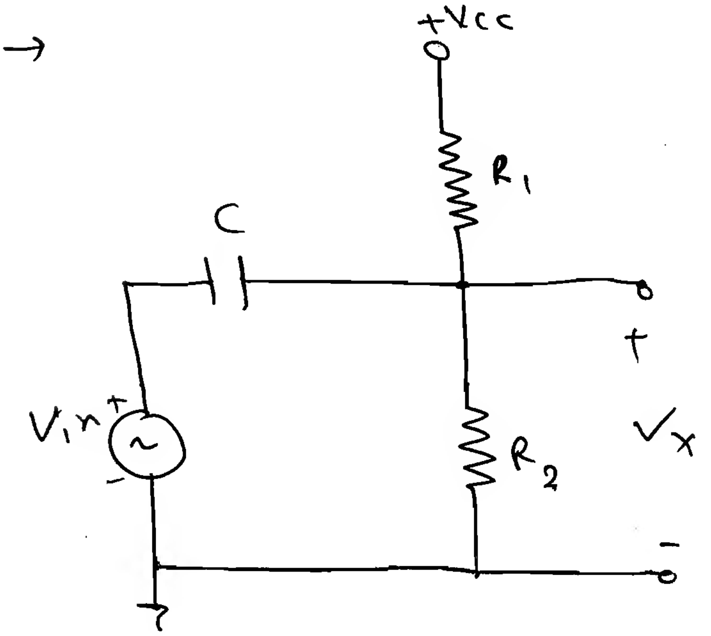
$\bar{Q} = 0 \Rightarrow$ T is OFF

$\bar{Q} = 1 \Rightarrow$ T is ON.

* Schmitt Trigger using 555 Timer:-



→



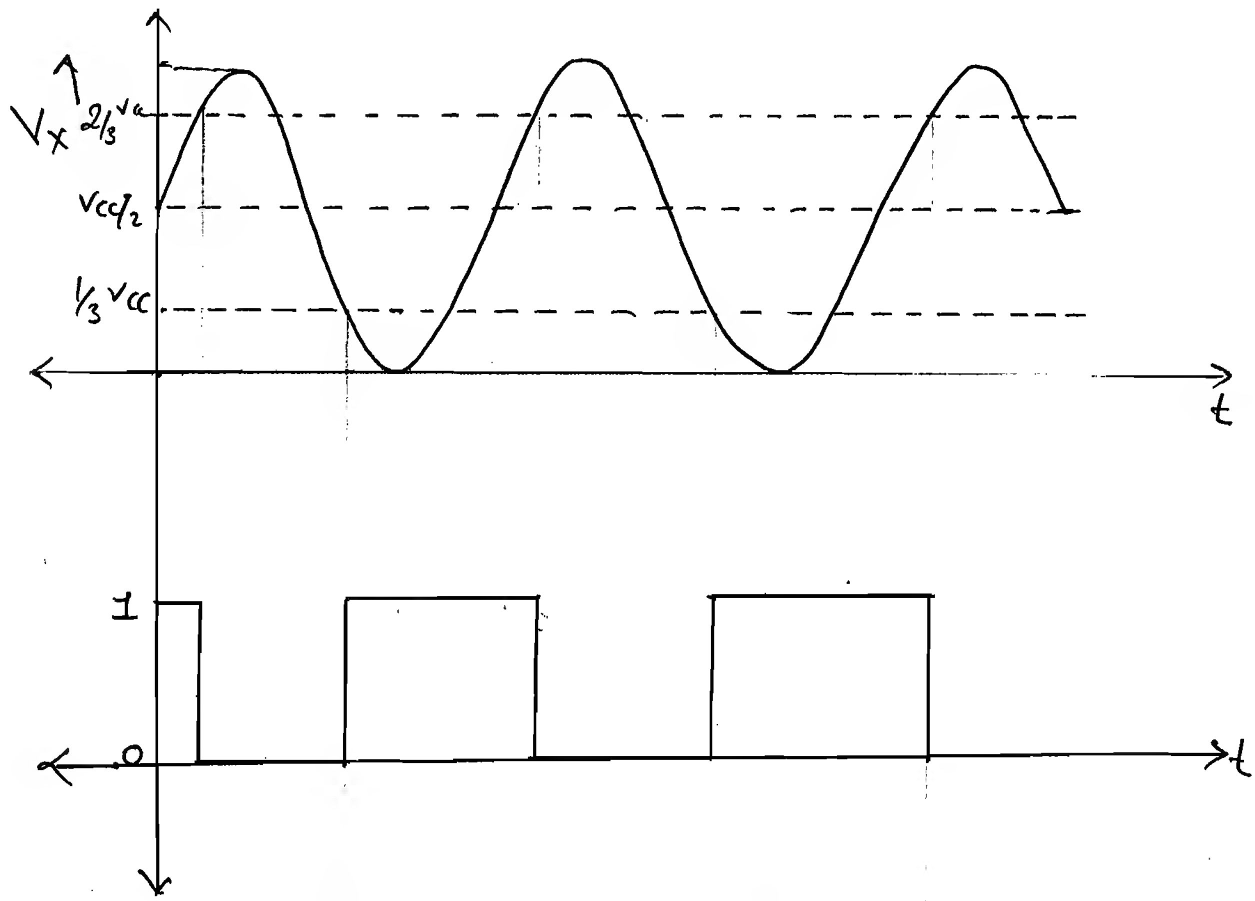
$$V_x = \frac{R_2 V_{cc}}{R_1 + R_2} + V_{in}.$$

↑ Dc picture. ↑ AC picture.

when $R_1 = R_2$

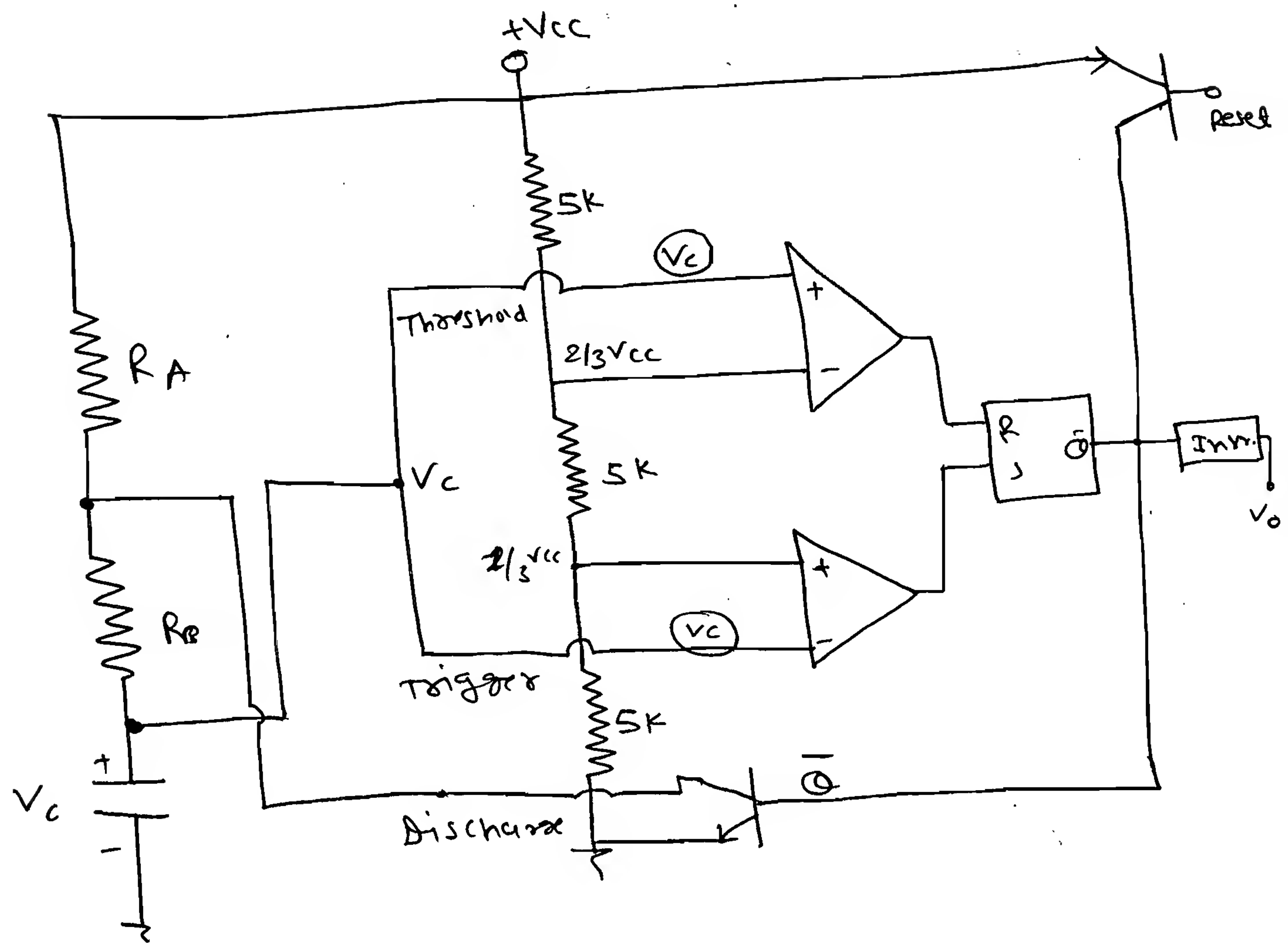
$$\boxed{V_x = \frac{V_{cc}}{2} + V_{in}}$$

	R	S	$\bar{Q}$	Q = O/P
$V_x = 0$	0	1	0	1
$V_x = \frac{V_{cc}}{2}$	0	0	0	1 (previous)
threshold $> 2/3 V_{cc}$ $V_x > \frac{2}{3} V_{cc}$	1	0	1	0
$V_x = \frac{2}{3} V_{cc}$	0	0	1	0 (previous
$V_x < \frac{1}{3} V_{cc}$ trigger $< 1/3 V_{cc}$	0	1	0	1



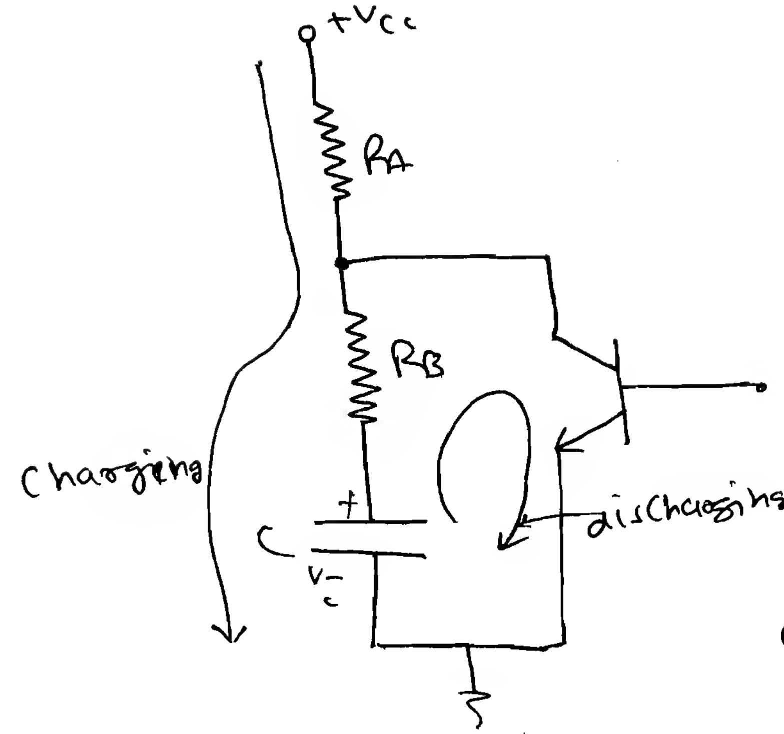
[Square wave].

* Astable Multivibrators using 555 timer:

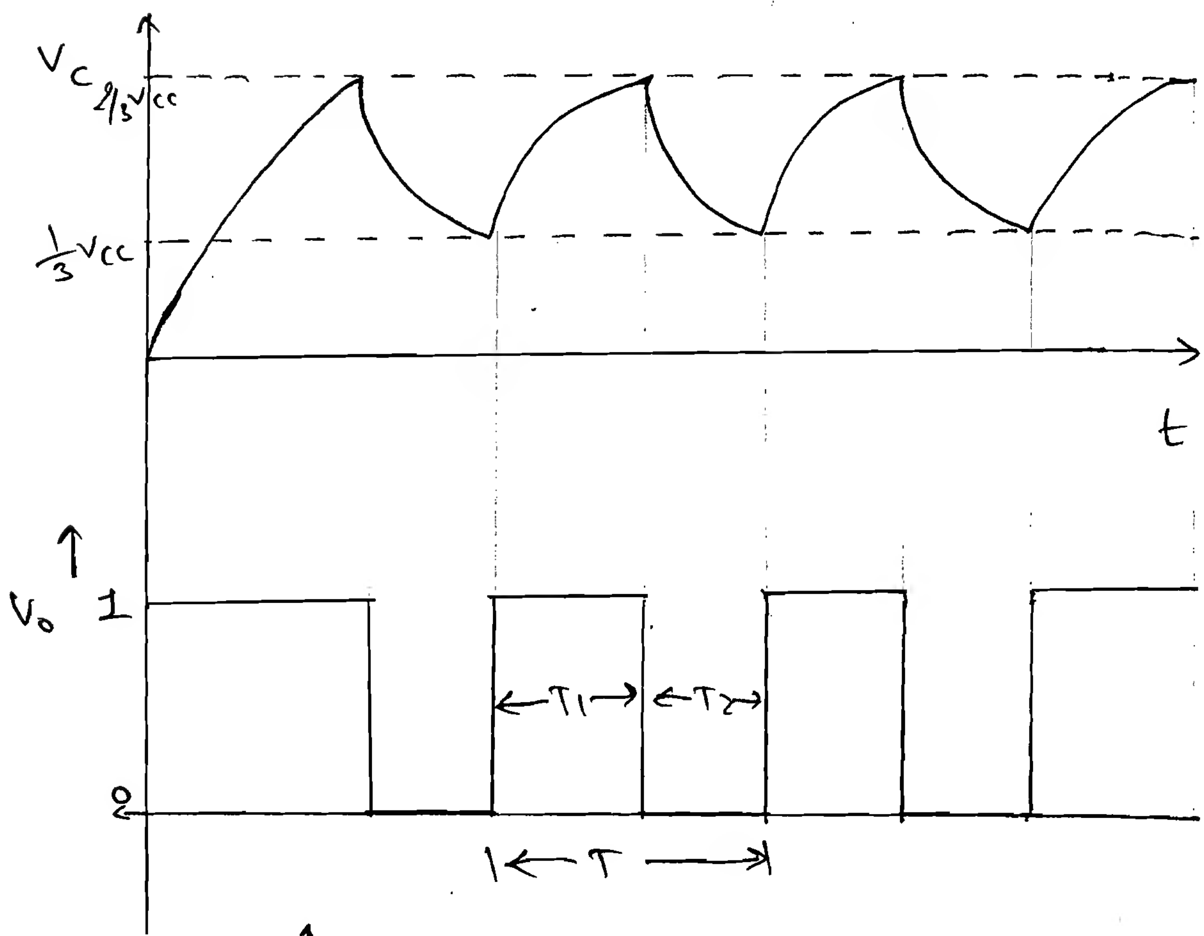


	R	S	$\bar{Q}$	Q	
$V_c = 0$	0	1	0	1	Transistor OFF, Capacitor Charge.
$V_c > \frac{1}{3}V_{cc}$	0	0	0	1	Transistor OFF. Capacitor Charge.
$V_c > \frac{2}{3}V_{cc}$	1	0	1	0	Transistor ON. Capacitor discharge.
$V_c < \frac{1}{3}V_{cc}$	0	1	0	1	Transistor OFF, Capacitor discharge.

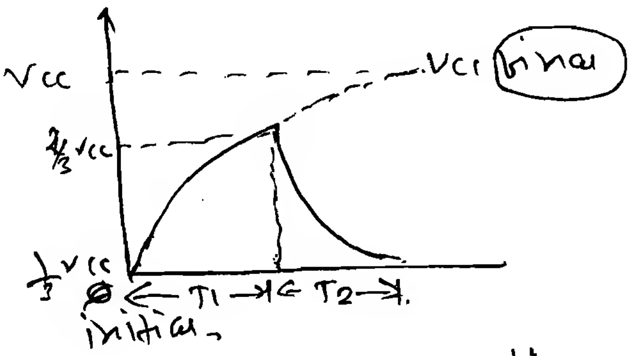
⇒



$\bar{Q} = 0$, $T \to OFF$
Cap. charge.
$\bar{Q} = 1$, $T \to ON$.
Cap. discharge through BJT



*



$$V_c(t) = [V_{initial} - V_{final}]e^{-t/\tau} + V_{final}.$$

$$\therefore V_c(t) = \left[\frac{1}{3}V_{CC} - V_{CC}\right] \cdot e^{-t/\tau} + V_{CC}.$$

at $t = T_1$ $\quad V_c(t) = \frac{2}{3}V_{CC}.$

$$\therefore \frac{2}{3}V_{CC} = -\frac{2}{3}V_{CC} \cdot e^{-T_1/\tau} + V_{CC}.$$

$$\therefore -\frac{1}{\cancel{3}}\cancel{V_{CC}} = -\frac{2}{\cancel{3}}\cancel{V_{CC}} \cdot e^{-T_1/\tau}$$

$$\therefore e^{-T_1/\tau} = \frac{1}{2}.$$

$$\therefore \frac{T_1}{RC} = \ln 2.$$

$$\therefore \boxed{T_1 = 0.69\,RC.}$$

→ The charging time const. $= (R_A + R_B)\,C.$

∴ similary discharging time const. $= R_B C.$

$$\therefore \boxed{T_1 = 0.69\,(R_A + R_B)\,C.}$$

$$\therefore \boxed{T_2 = 0.69\,R_B C.}$$

$$\therefore \text{Total } \boxed{T = T_1 + T_2.}$$

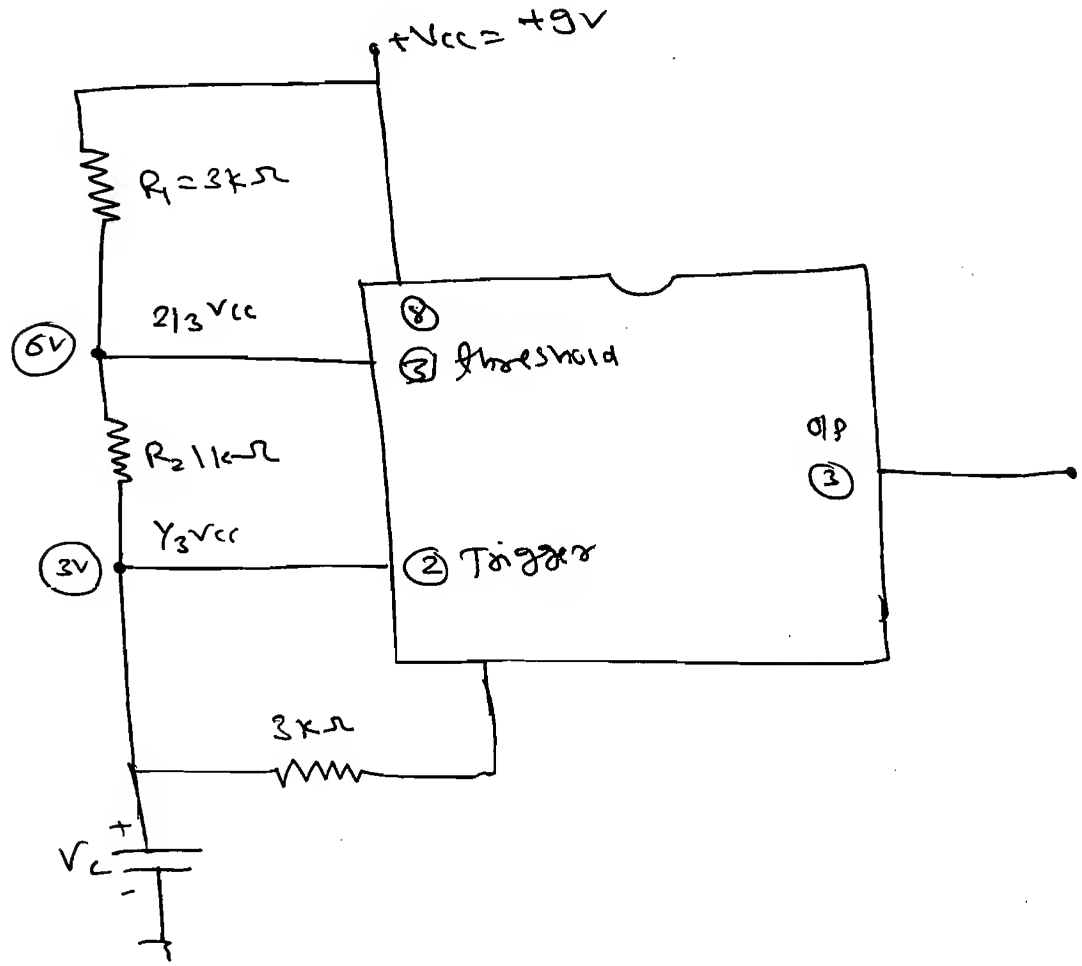
$$\text{Duty cycle} = \frac{T_{ON}}{T}$$

$$= \frac{0.\cancel{69C}(R_A + R_B)}{0.\cancel{69C}(R_A + 2R_B)}.$$

$$\boxed{\text{Duty cycle.} = \frac{R_A + R_B}{R_A + 2R_B}}.$$

for 50% Duty cycle $\quad R_A = 0 \Rightarrow \quad D.C. = \frac{R_B}{2R_B} = 50\%.$

Ex-1 GATE: find the Range of capacitor voltage V_c if the supply voltage is +9V in the Astable multivibrator is given.



(A) 3V to 6V.

(B) 3V to 5V.

(C) 3V to 4V.

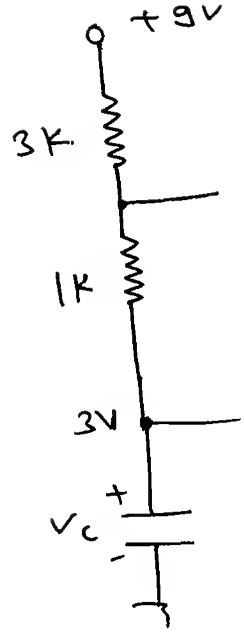
(D) None.

NOTE: A 555 timer change its states:

① when threshold just $> \frac{2}{3} V_{cc}$

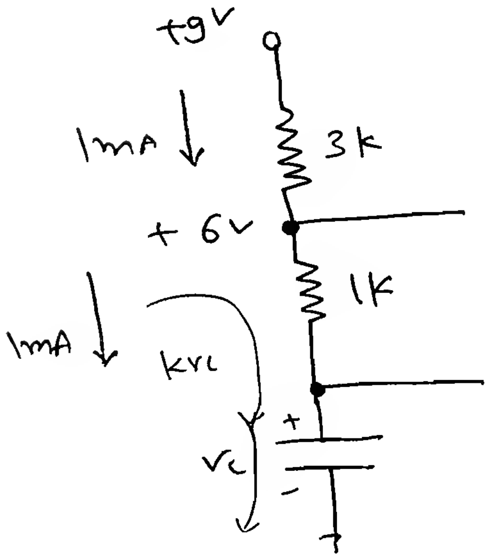
② when trigger just $< \frac{1}{3} V_{cc}$.

solution: ① $V_{trigger} = \frac{1}{3} V_{cc} = 3V.$



So, $\boxed{V_c = 3V}$

② $V_{threshold} = \frac{2}{3}V_{cc} = \frac{2}{3} \times 9 = 6V.$



$I = \frac{9-6}{3k} = 1mA.$

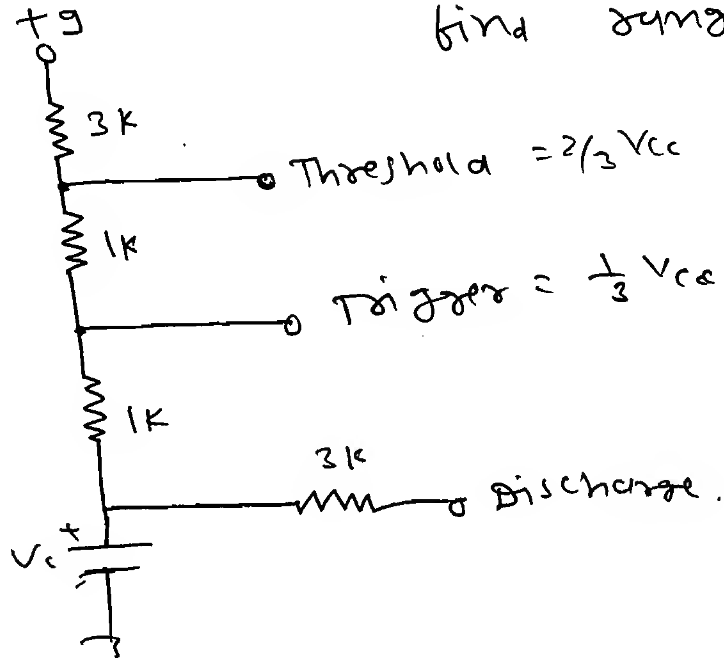
$+6 - (1m \times 1k) - V_c = 0.$

$\therefore \boxed{V_c = +5V}$

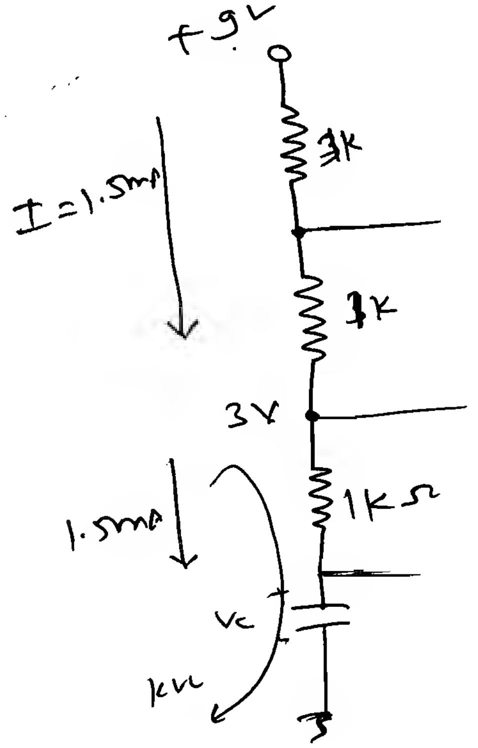
So, range of Vc is $\boxed{3V \text{ to } 5V}$

Ex-2

find range of Vc.



Ans: (1) Trigger $= \frac{1}{3} V_{cc} = \frac{9}{3} = 3V.$



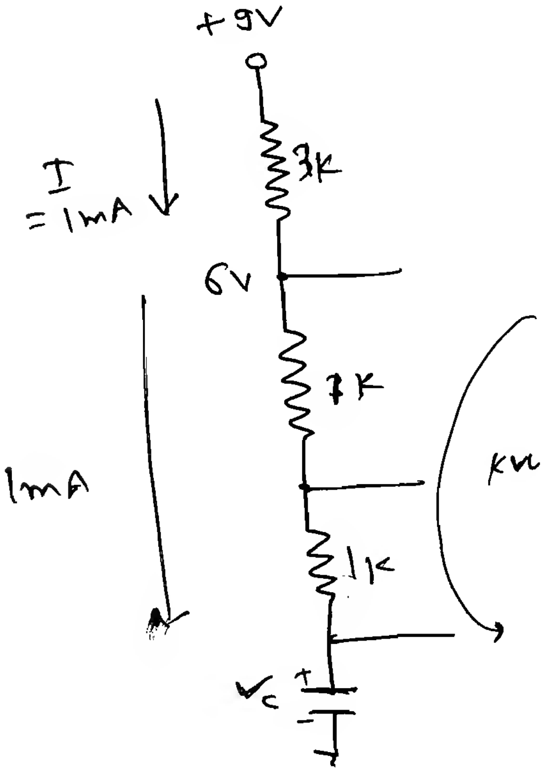
$$I = \frac{9-3}{(3+1)k} = \frac{6}{4}$$

$$\boxed{I = 1.5mA}$$

$$\therefore \ 3V - (1.5 \times 1) - V_c = 0$$

$$\therefore \ \boxed{V_c = 1.5V}$$

(2) Threshold $= \frac{2}{3} V_{cc} = \frac{2}{3} \times 9 = 6V.$

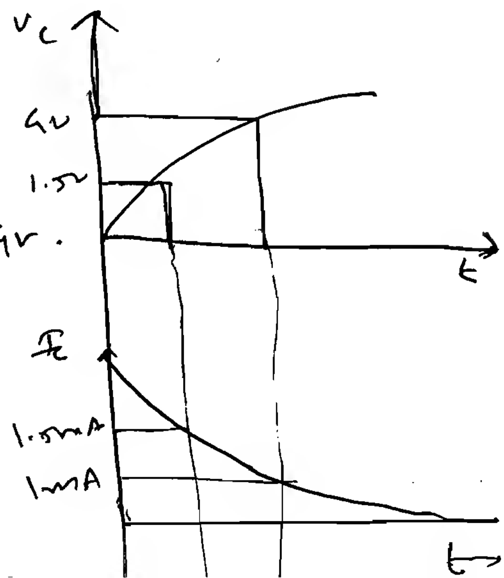


$$I = \frac{9-6}{1K} = 1mA.$$

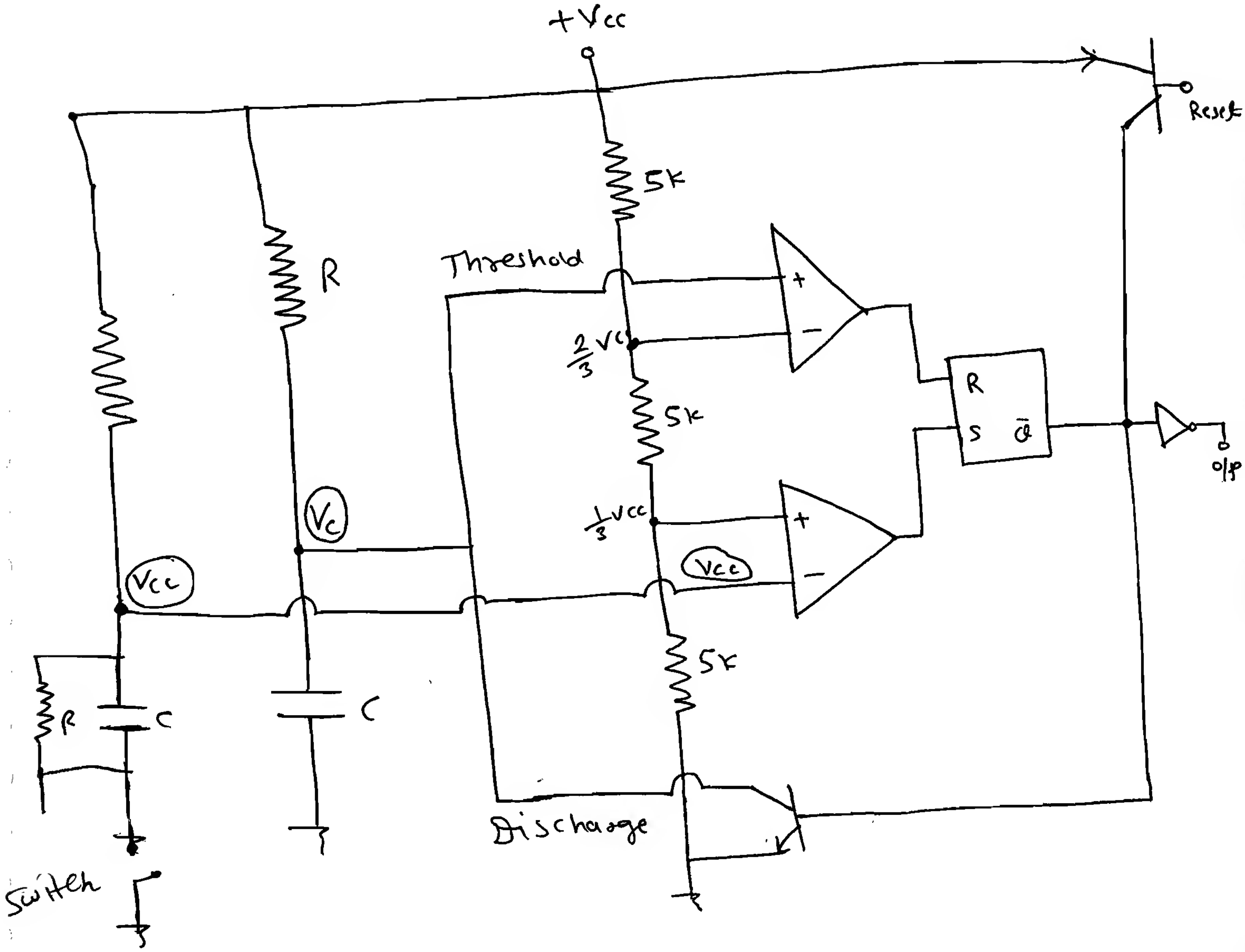
$$6 - (2 \times 1) - V_c = 0$$

$$\boxed{V_c = 4V}$$

So, range of V_c $\therefore$ 1.5 to 4V.

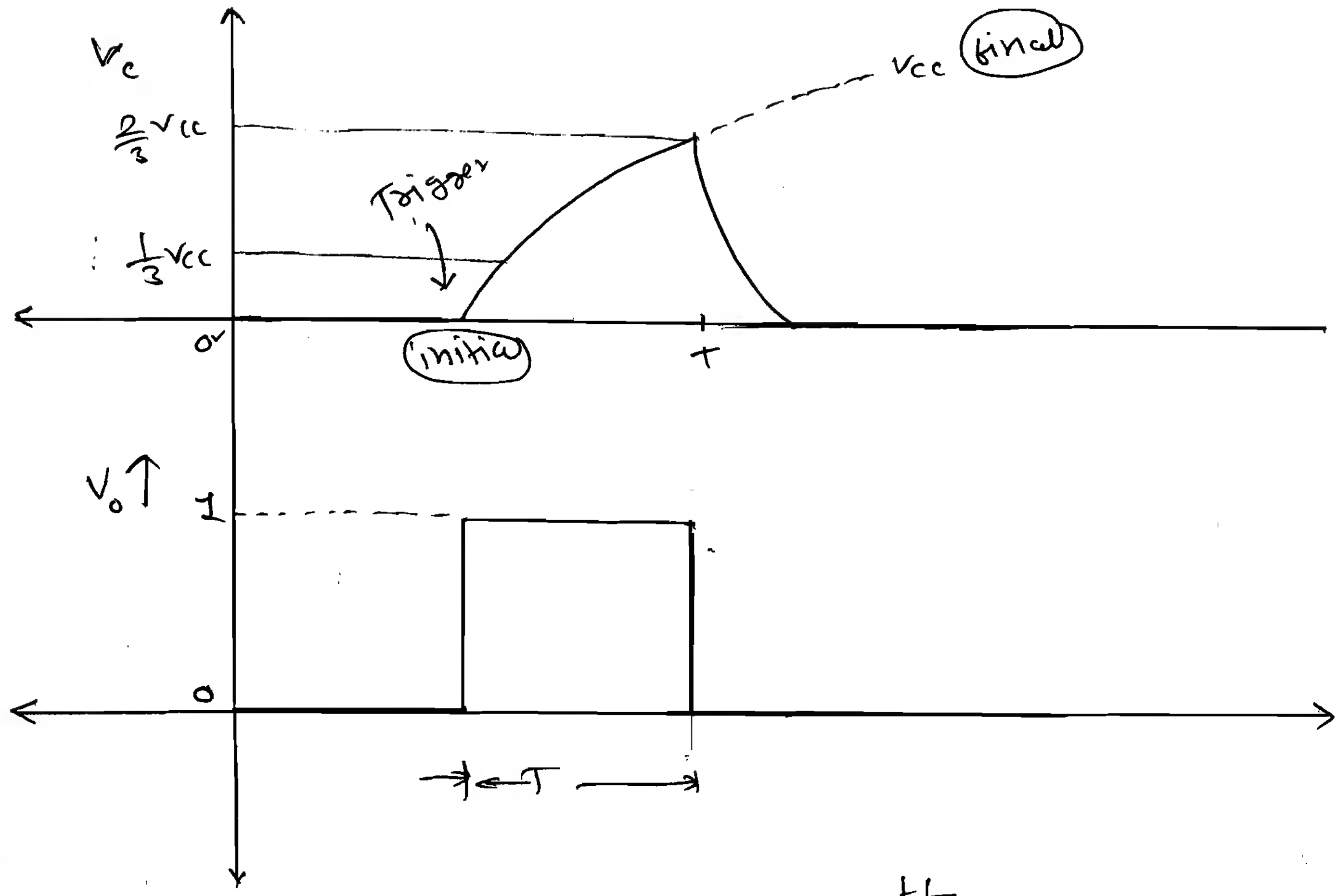


* Monostable Multivibrator using 555 Timer:



* Truth Table:

V_c	R	S	$\bar{Q}$	o/p = Q	
let us assume $V_c > 2/3$	1	0	1	0	Transistor ON, capacitor discharge.
$V_c = 0$	0	0	1	0	previous sate.
Let us give a trigger. $V_c = 0$	0	1	0	1	Transistor OFF, Capacitor charge.
$V_c \geq \frac{1}{3} V_{cc}$	0	0	0	1	previous state.
$V_c > \frac{2}{3} V_{cc}$	1	0	1	0	Transistor ON. capacitor discharge
$V_c = 0$	0	0	1	0	(previous state)



$$\rightarrow \quad V_c(t) = \left[V_c(\text{initial}) - V_c\,\text{final}\right] \cdot e^{-t/\tau} + V_c(\text{final}).$$

$$V_c(t) = \left[0 - \tfrac{2}{3}V_{cc}\right] \cdot e^{-t/\tau} + V_{cc}$$

$$\therefore \quad V_c(t) = V_{cc}\left[1 - e^{-t/\tau}\right]$$

at $t = T$ $\quad V_c(t) = \frac{2}{3}V_{cc}$

$$\therefore \quad \frac{2}{3}\cancel{V}_{cc} = \cancel{V}_{cc}\left[1 - e^{-T/RC}\right].$$

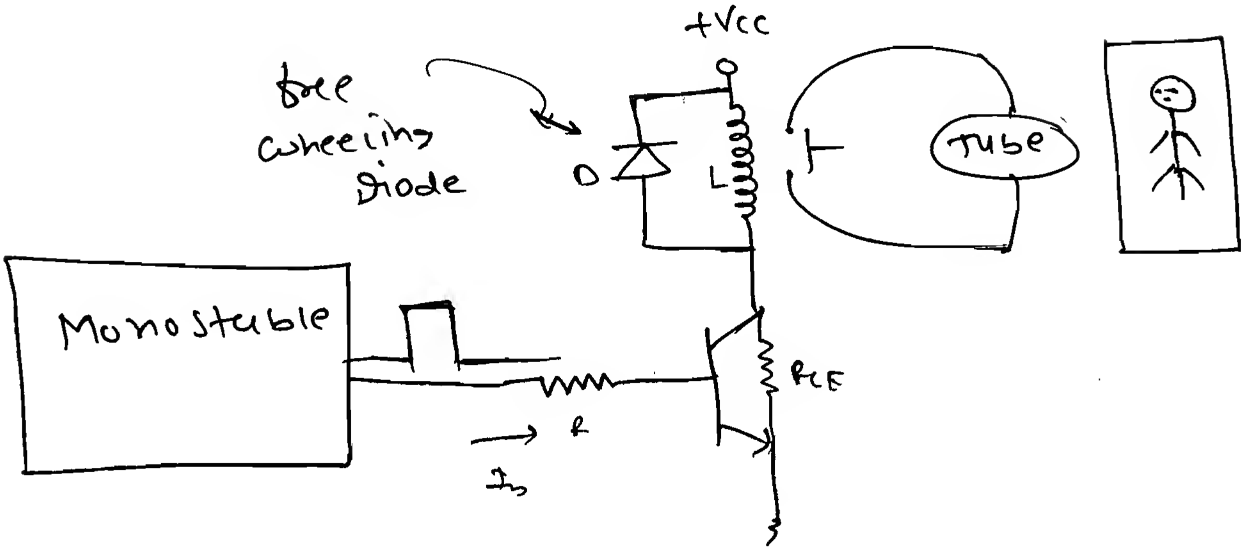
$$\therefore \quad e^{-T/RC} = 1 - 2/3.$$

$$\therefore \quad e^{-T/RC} = \frac{1}{3}.$$

$$\therefore \quad \boxed{T = 1.1RC.}$$

* Application of Monostable multivibrator

→



⇒ never Open inductor never Short Capacitor directly.

→ Inductor never allow Sudden Change in current and capacitor never allow sudden change voltage.

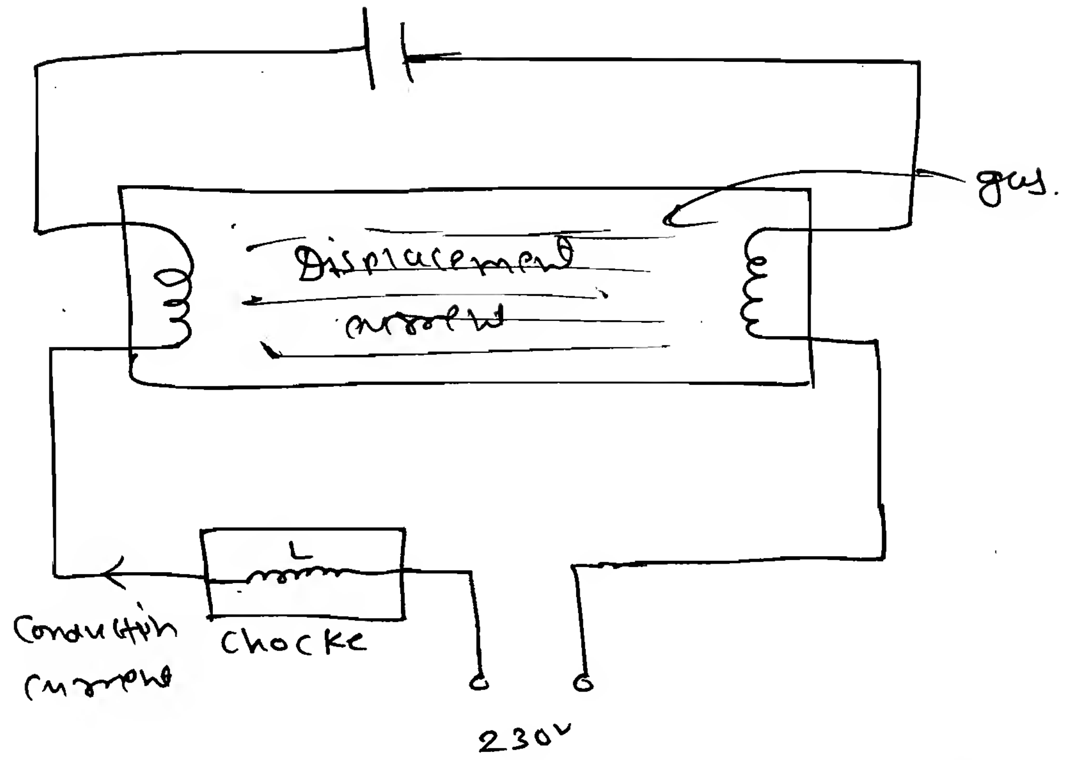
→ Now, as pulse comes Transistor is on over a period T which is on the X-ray machine and we will get X-Ray.

→ But when pulse fall from high to Low Transistor is ~~on~~ off and O.C. Therefore ∈ inductor current has no path to flow and generate a very large voltage.

$v = L\frac{di}{dt} = \frac{1\times10^{-3} \times 1m}{10^{-9}} = 1000V$. This voltage will damage the transistor every time. If Diode is not put across the inductor.

→ ~~Because~~ Diode provide a closed loop to flow inductor current. and Diode is called free wheeling diode.

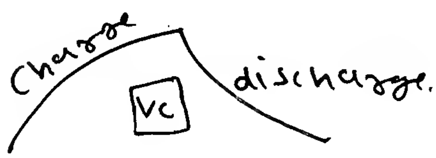
* Tubelight



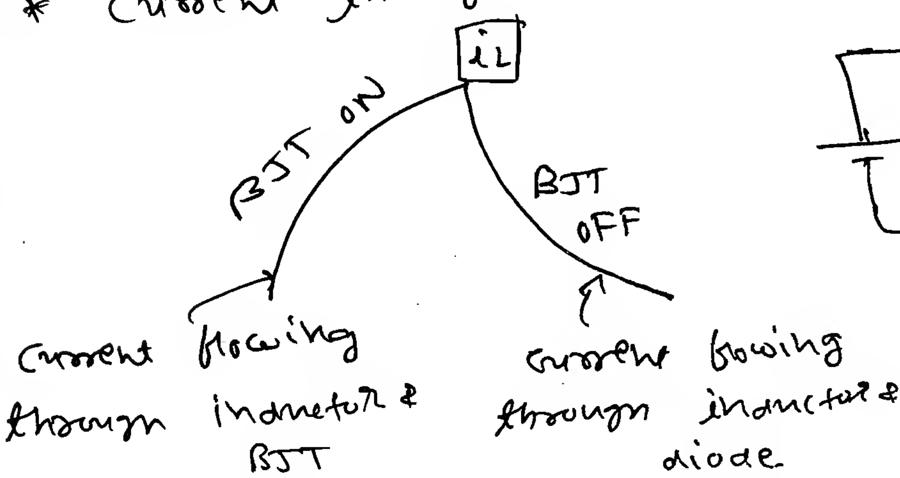
→ when capacitor o.c. then inductor ~~current~~ voltage is very high. which is provided to gas inside the tube and light will be ~~...~~ blow.

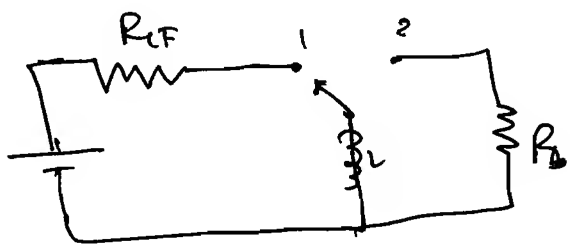
→ capacitor is starter and inductor is chock.

* Voltage across capacitor:



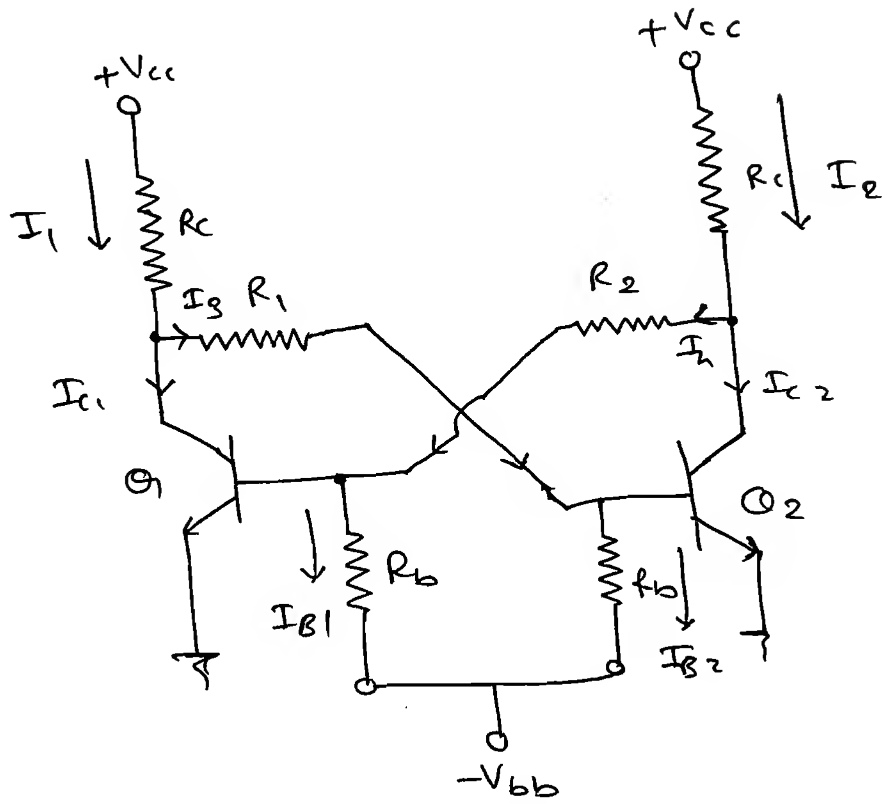
* Current through inductor.



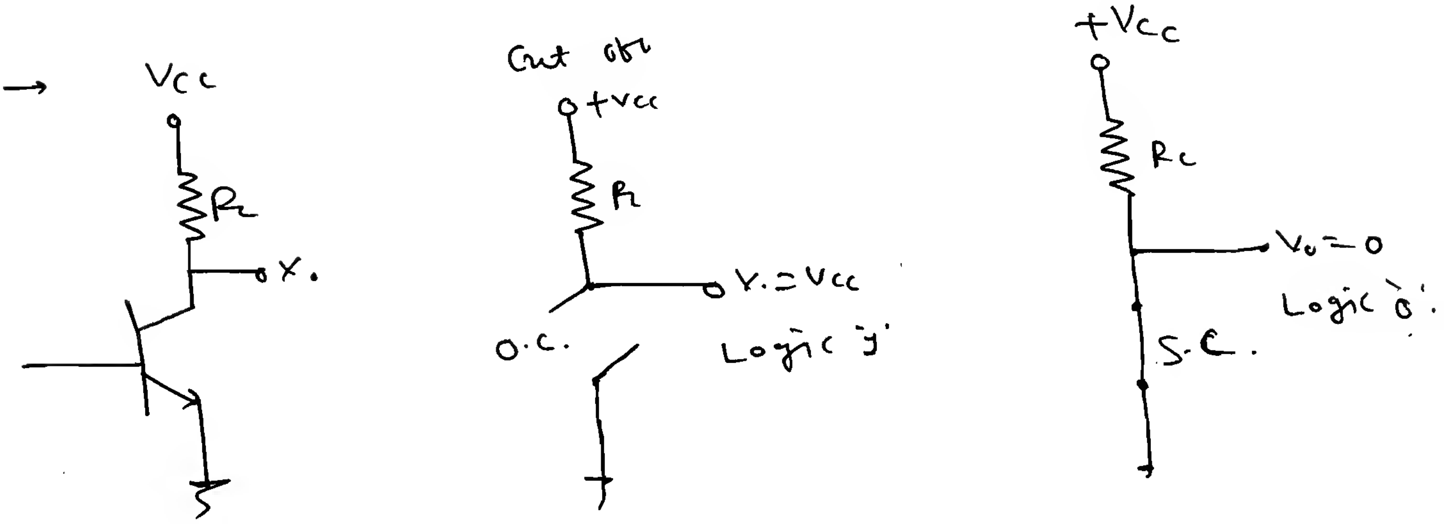


☆ Multivibrators Using BJT:

① Bistable multivibrators:



→



→ $I_1 = 1.0000012$ mA

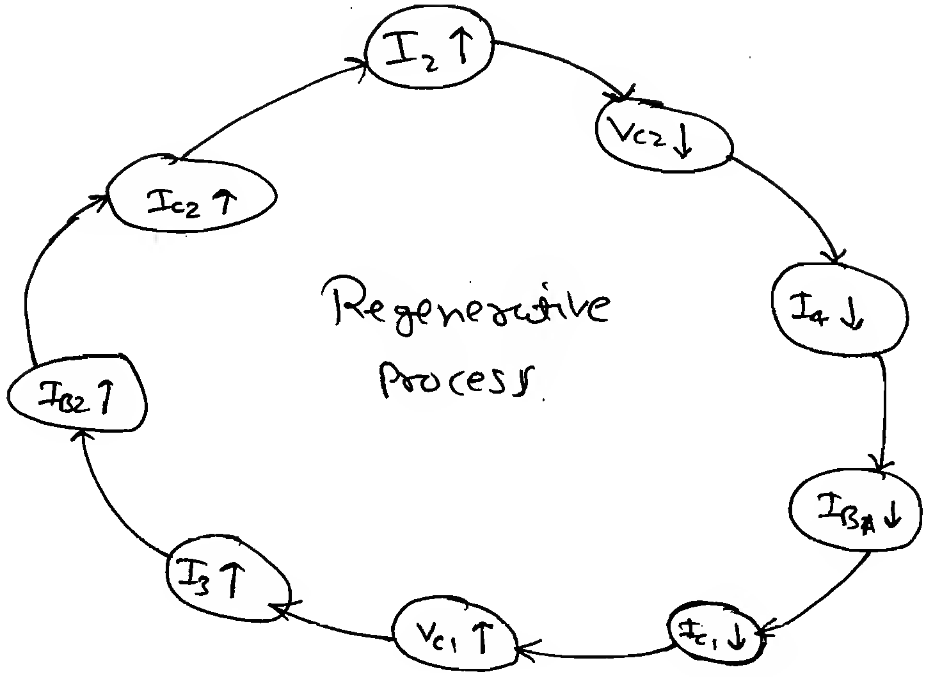
$I_2 = 1.000013$ mA

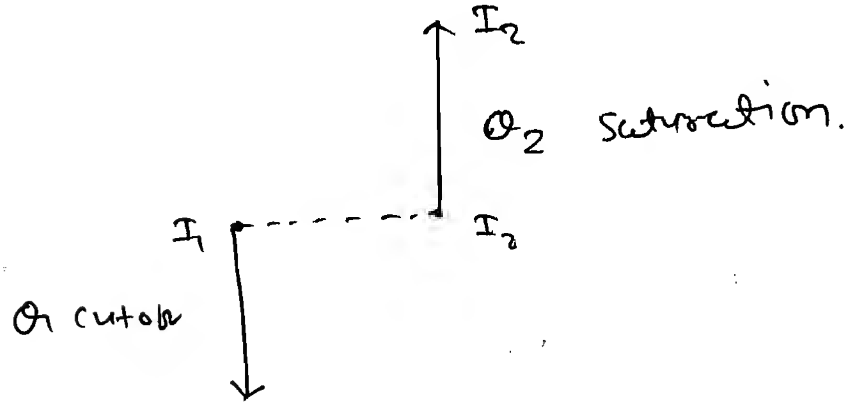
$I_2 > I_1$

$\therefore V_{c2} = V_{cc} - I_2 R_c > V_{c1} = V_{cc} - I_1 R_c.$

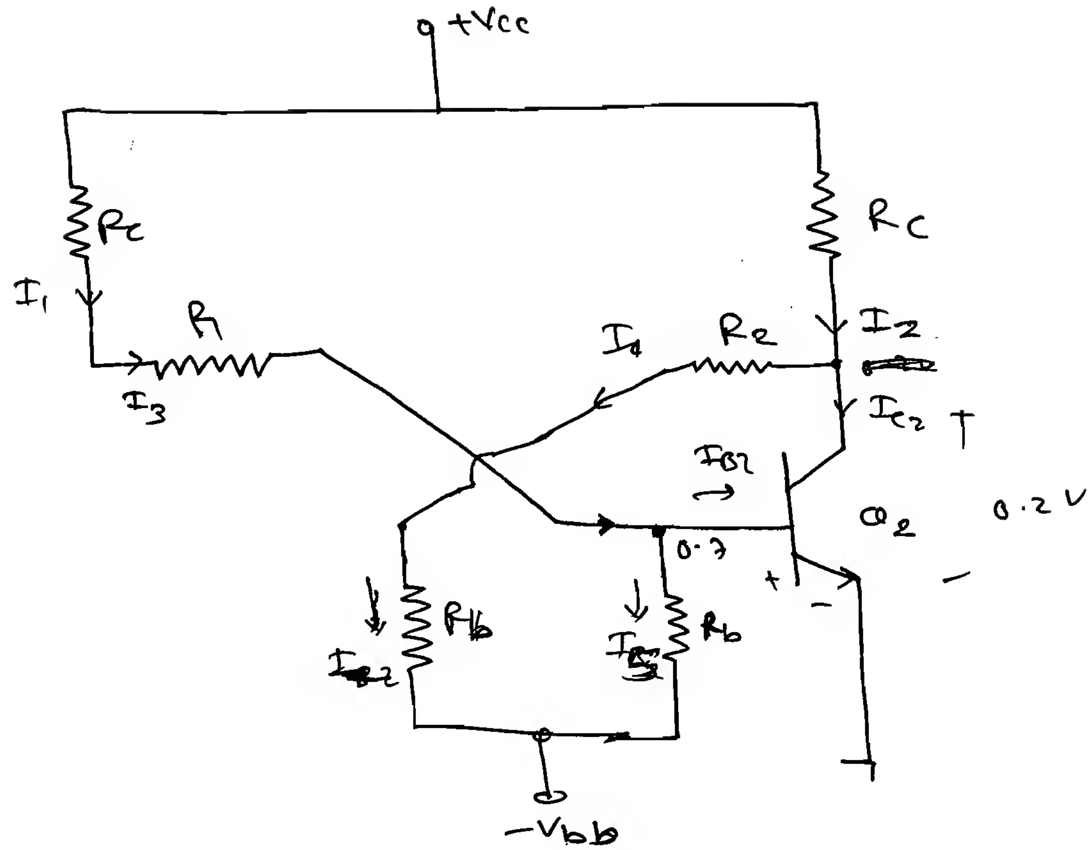
∴ Let us assume,

$$V_{C2} = V_{CC} - I_2 R_C < V_{C1} = V_{CC} - I_1 R_C.$$





* Calculate the node voltages and branch current if Q_1 is in cut off and Q_2 is in saturation.



$\rightarrow$ $I_{B2} = I_1 - I_5$

$I_{c2} = I_2 - I_4.$

$\therefore \quad I_1 = I_3 = \dfrac{V_{CC} - 0.7}{R_C + R_1}.$

$\therefore \quad I_2 = \dfrac{V_{CC} - 0.2}{R_C}.$

$\therefore \quad I_4 = \dfrac{V_{C2} - (-V_{bb})}{R_b + R_1}.$

But $I_5 = \dfrac{0.7 + V_{bb}}{R_b}.$

$\rightarrow$ Q_2 is in saturation so,

$\beta_{force} < \beta_{active}.$

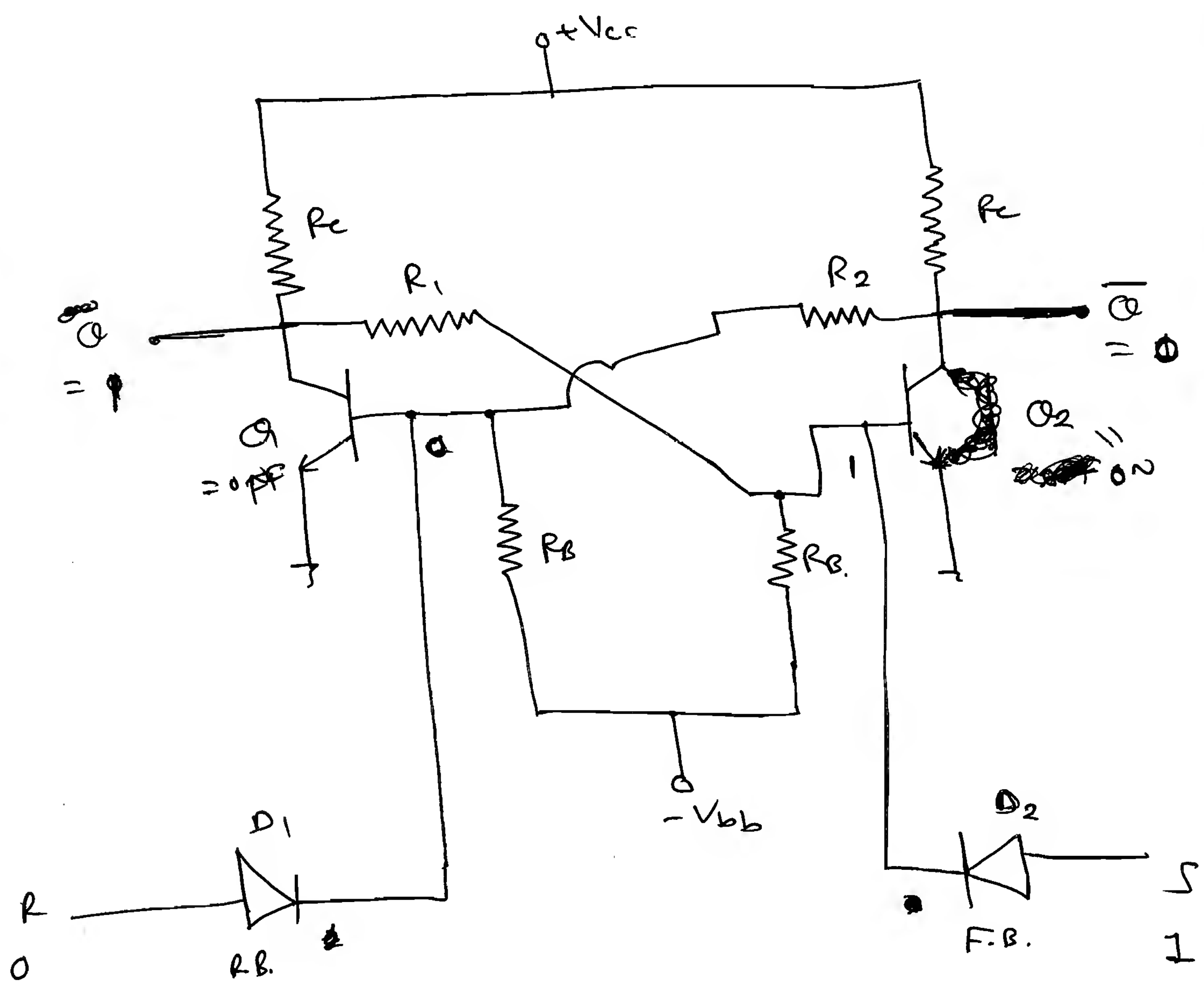
$\therefore \quad \left| \dfrac{I_{c2}}{I_{B2}} \right| < \beta_{active}.$

$$\therefore \boxed{\left|\frac{I_2 - I_4}{I_1 - I_5}\right| < \beta_{active}}$$

* Two Types of Triggering 4 Bistable circuits:

1. Asymmetrical triggering
2. Symmetrical triggering.

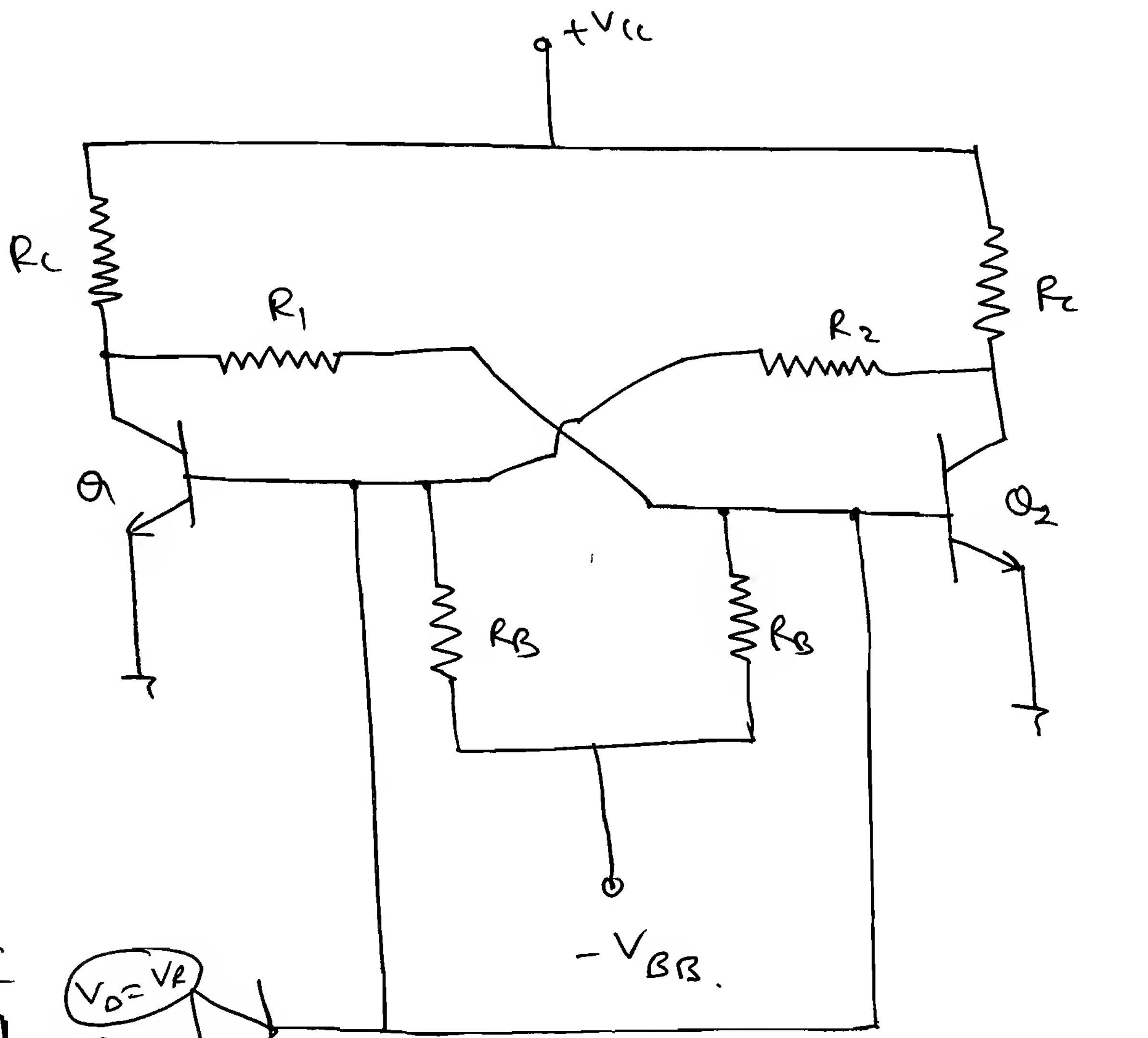
* Rs Flip flop using BJT:

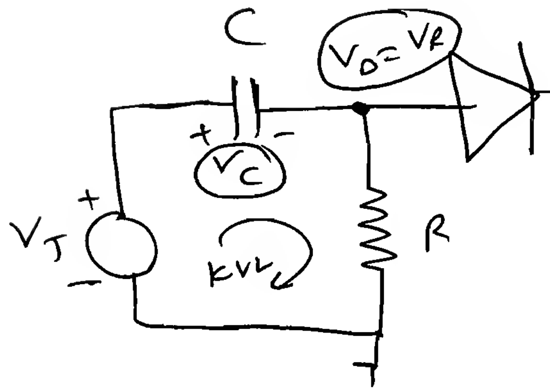


R	S	$\bar{Q}$	Q	D_1	D_2	T_1	T_2
0	0	Previous			Previous.		
0	1	0	1	R.B	F.B.	OFF	ON
1	0	1	0	F.B.	R.B.	ON	OFF
1	1	Don't try.		—	—	—	—

* Edge Trigger FF using BJT:

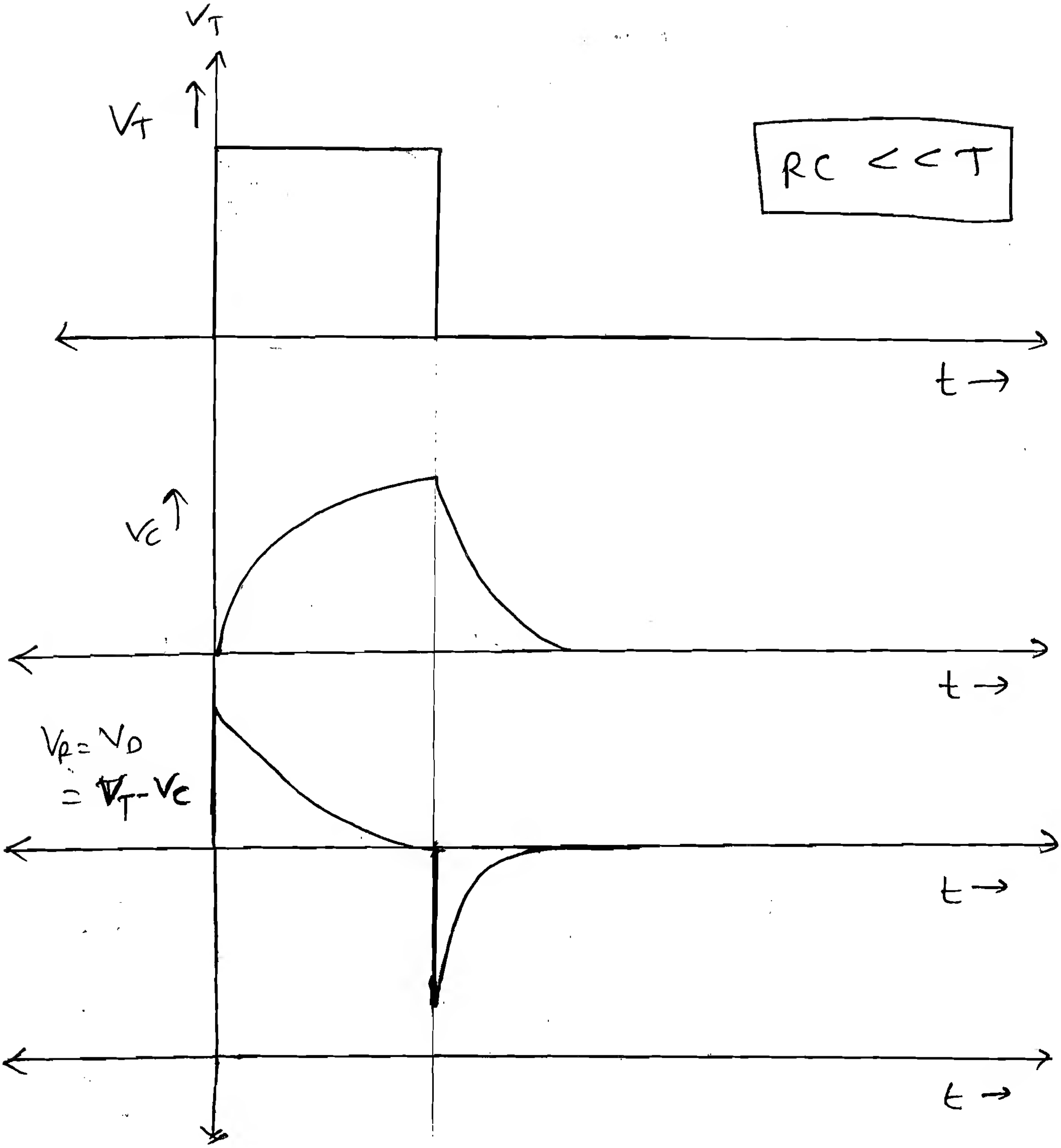
⇒





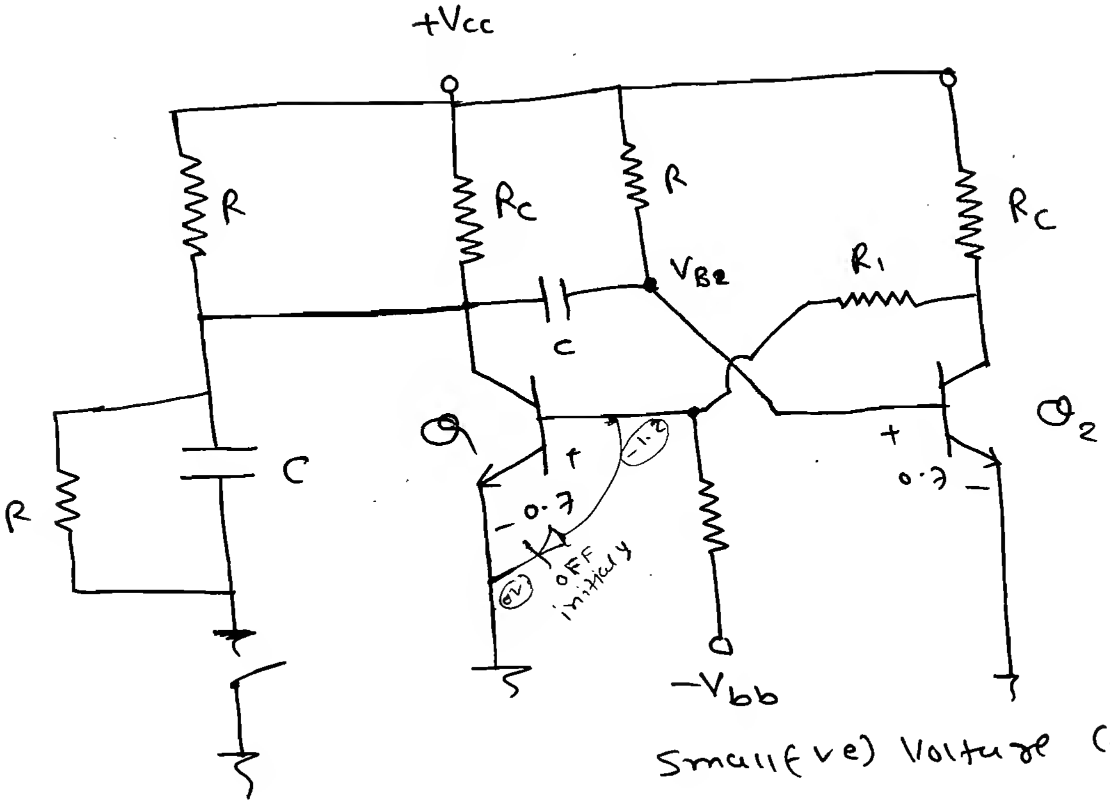
$$\therefore V_T - V_c - V_D = 0$$

$$\therefore \boxed{V_D = V_T - V_c}$$



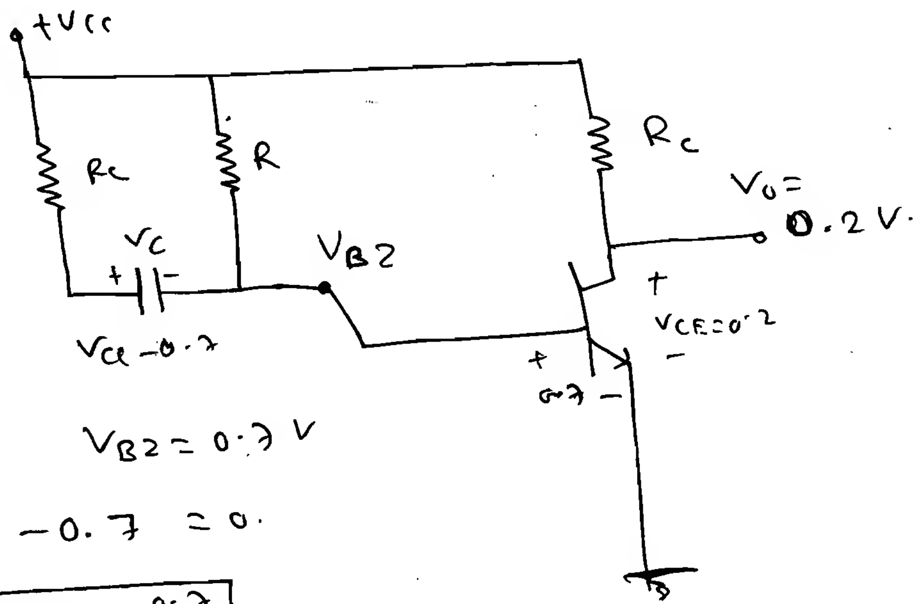
V_T
V_T
RC << T
t →
V_C
t →
$V_R = V_D$
$= V_T - V_C$
t →
t →

* Mono Stable Multivibrator using BJT:



Small(-ve) Voltage (-1.2V).

⇒ Consider initially Q_1 is OFF because of small negative voltage $(-V_{bb})$.



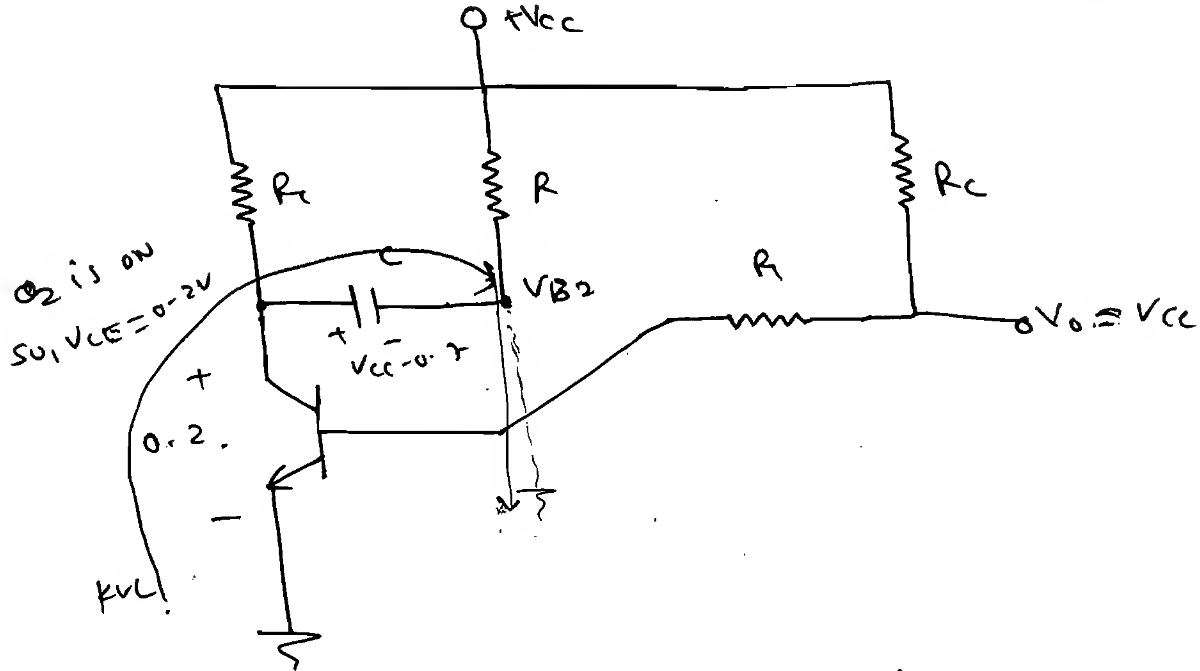
⇒ By KVL, $V_{B2} = 0.7\ V$

$\therefore V_{cc} - V_c - 0.7 = 0.$

$\therefore \boxed{V_c = V_{cc} - 0.7}$

⇒ So, Capacitor charges to $V_{cc} - 0.7\ V$.

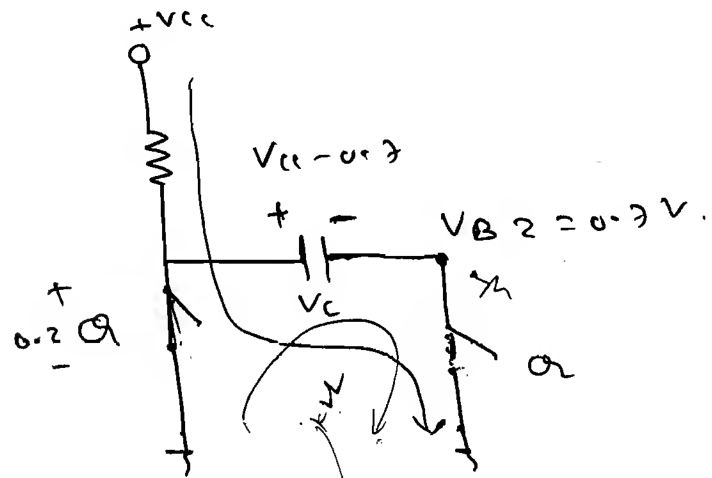
⇒ let us give an external trigger for a short duration, within no time Q_2 is OFF and Q_1 is ON.



By KVL, $+0.2 - V_{CC} + 0.7 - V_{B2} = 0$.

$\therefore V_{B2} = 0.9 - V_{CC}$

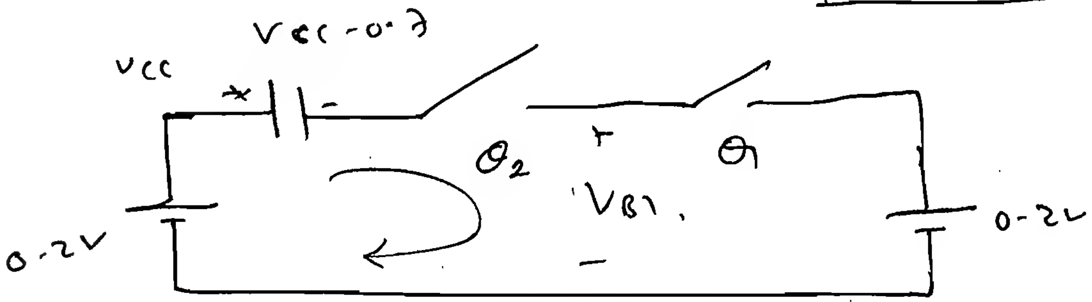
$\boxed{V_{B2} = -(V_{CC} - 0.9)\,V}$

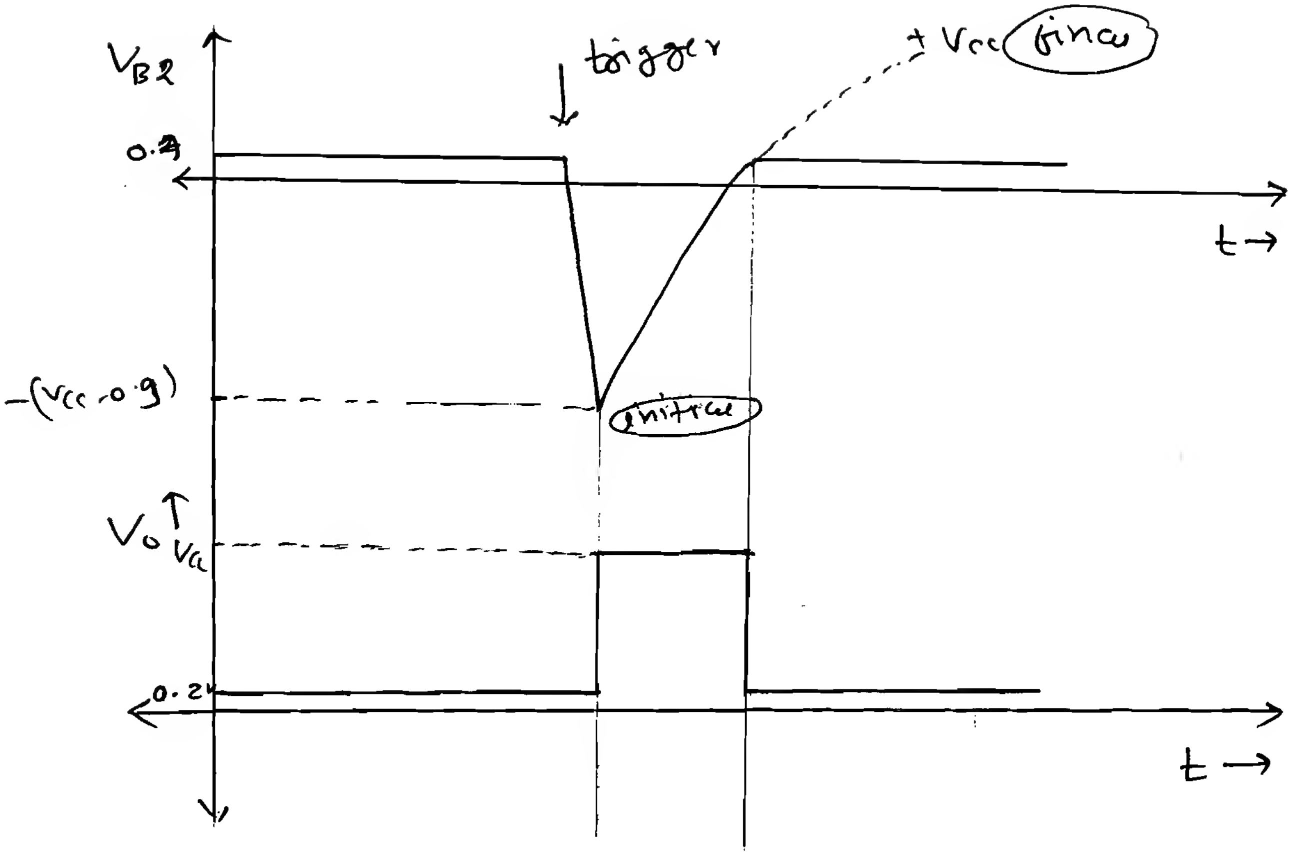


→ Q_1 = OFF Q_2 = ON ⇒ $V_C = V_{CC} - 0.7$.

→ Q_1 = ON Q_2 = OFF ⇒ $0.2 - V_{CC} + 0.7 - V_{B2} = 0$

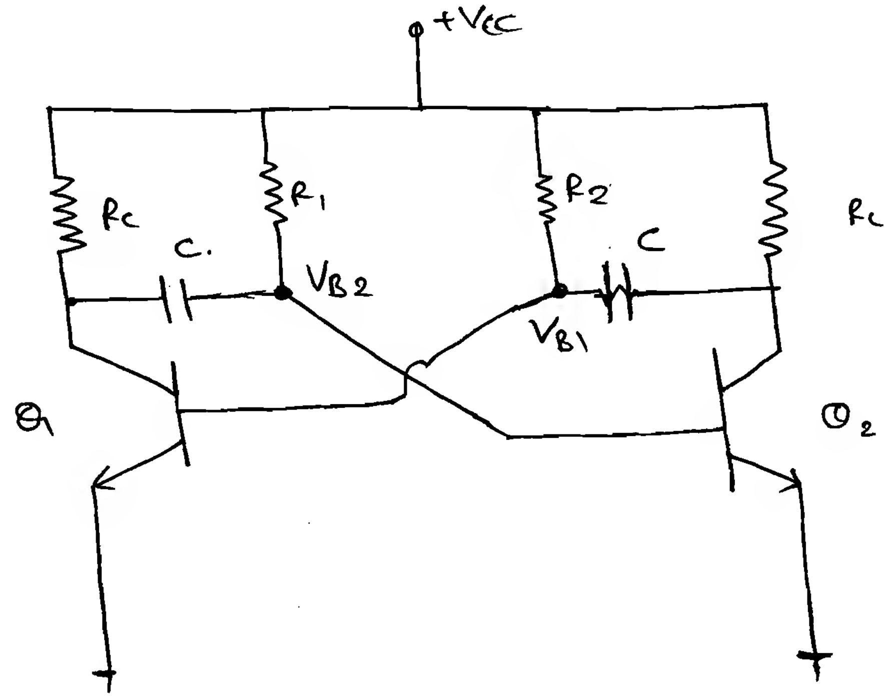
$\boxed{V_{B2} = -(V_{CC} - 0.9)\,V}$





* Astable Multivibrator: using BJT:

*

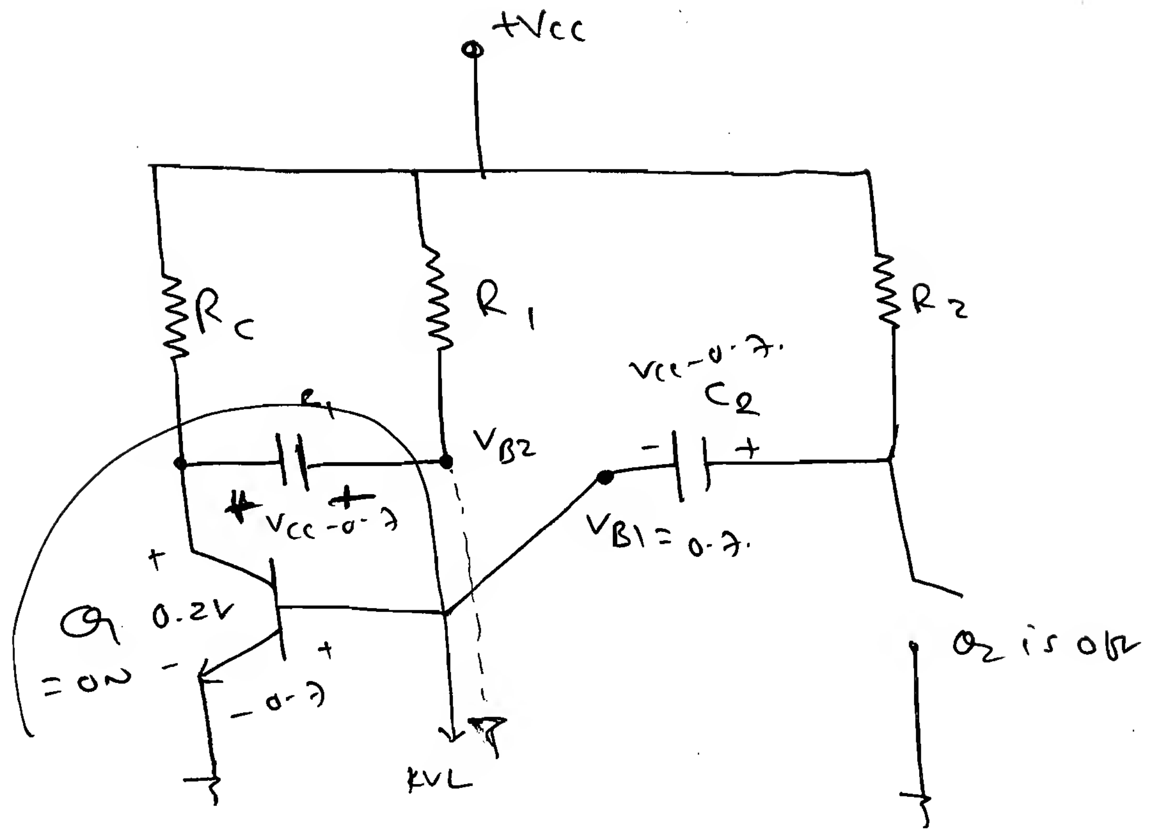


⇒ we will take 2 case:

① Q_1 is ON, Q_2 is OFF.

② Q_1 is OFF, Q_2 is ON.

case-(i) Let us, Q_1 = ON, Q_2 = OFF.



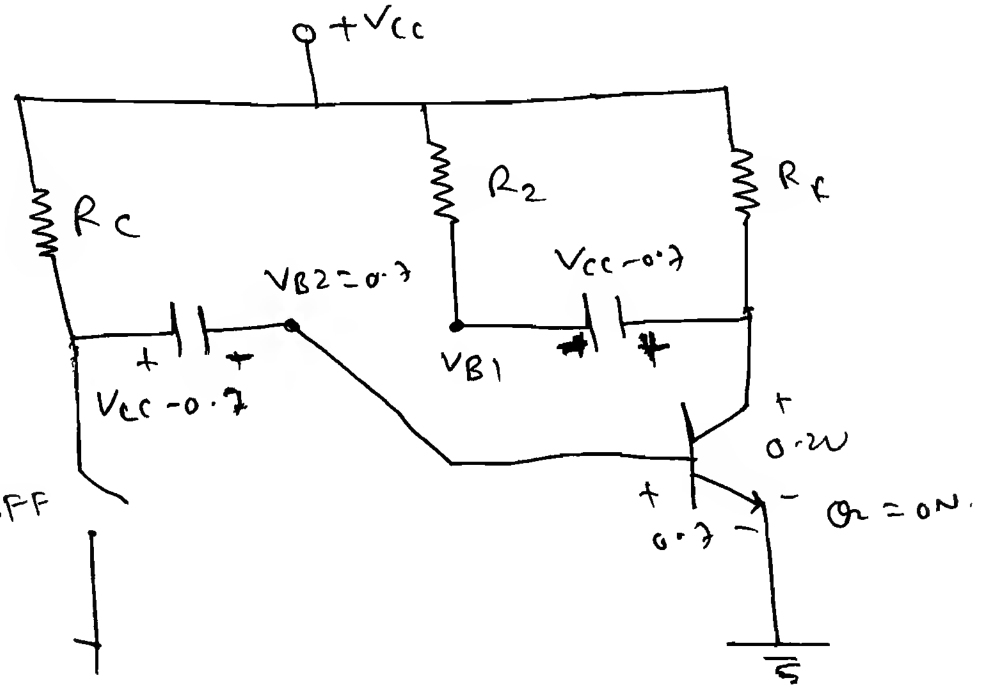
$\therefore$ $V_{B1} = 0.7.$

$\therefore$ or $-V_{cc} + 0.7 - V_{B2} = 0$

$\therefore$ $\boxed{V_{B2} = -(V_{cc} - 0.7).}$ toward Vcc

C_2 charges to $V_{cc} - 0.7$ V.

case-(ii)

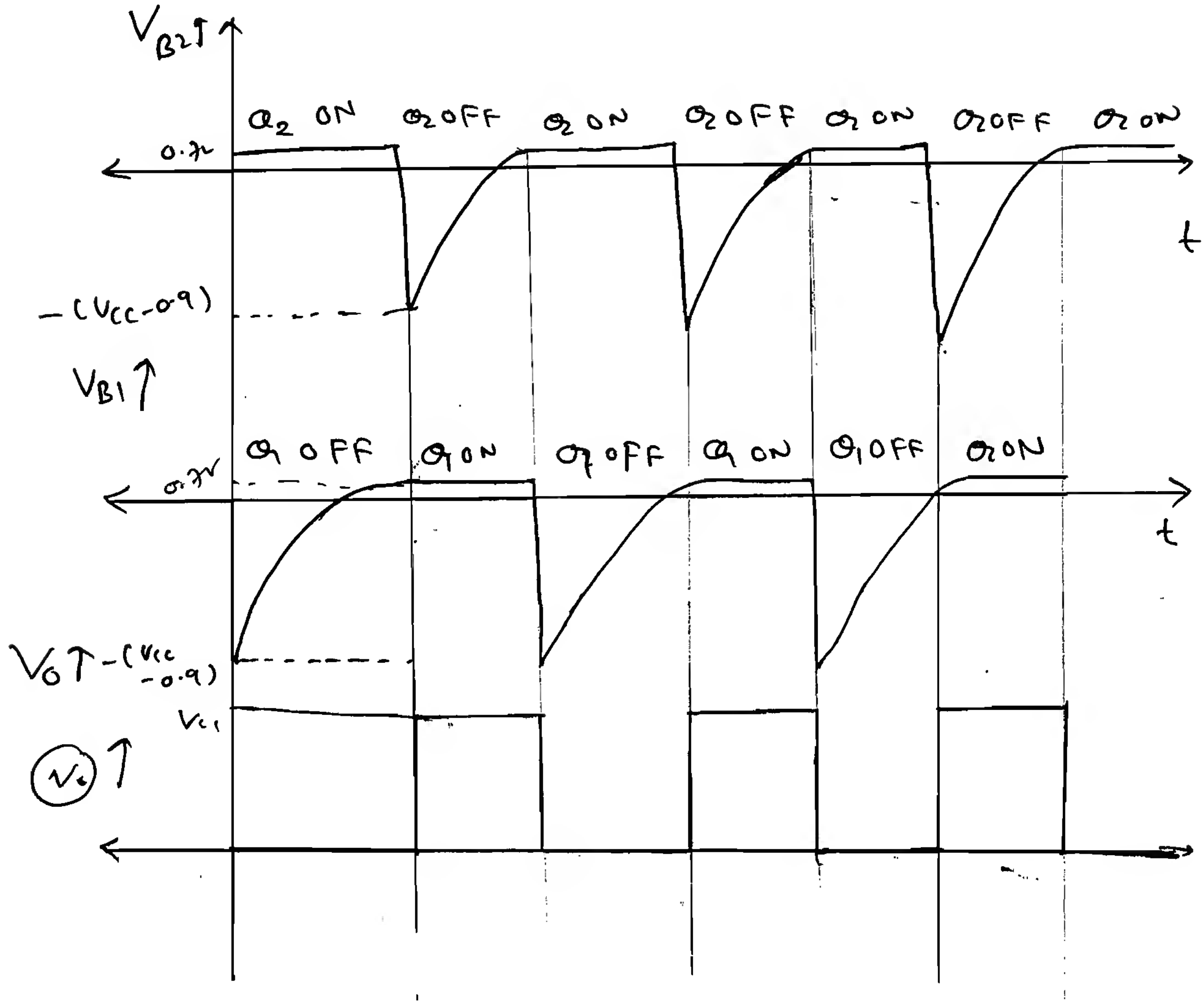


$Q_2 = $ OFF, $Q_1 =$ ON.

$\therefore \quad V_{B2} = 0.7V$

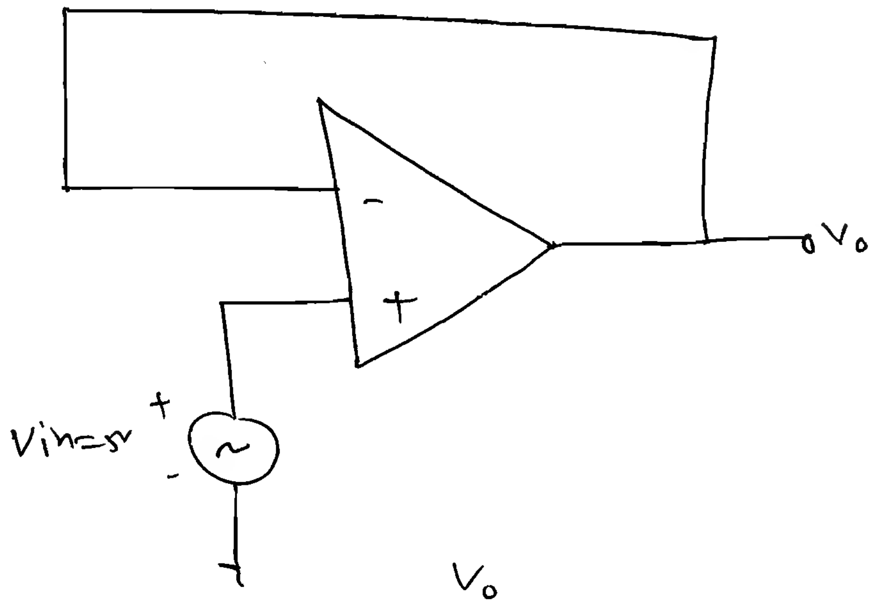
C_1 Charges to $V_{cc} - 0.7V$.

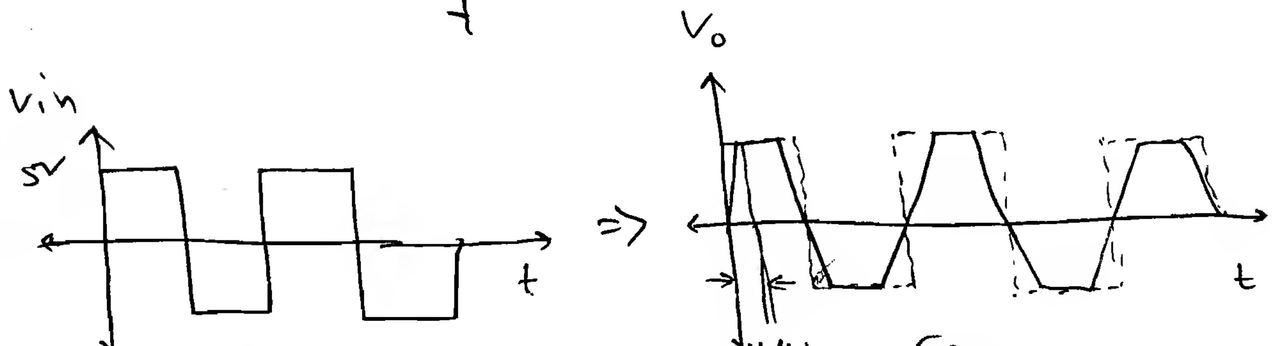
$\therefore \quad V_{B1}$ goes from $-(V_{cc} - 0.9)$ to V_{cc}



* Slew rate of an op-Amp :-

→ It is the maximum rate of change of output voltage for all possible input voltage.

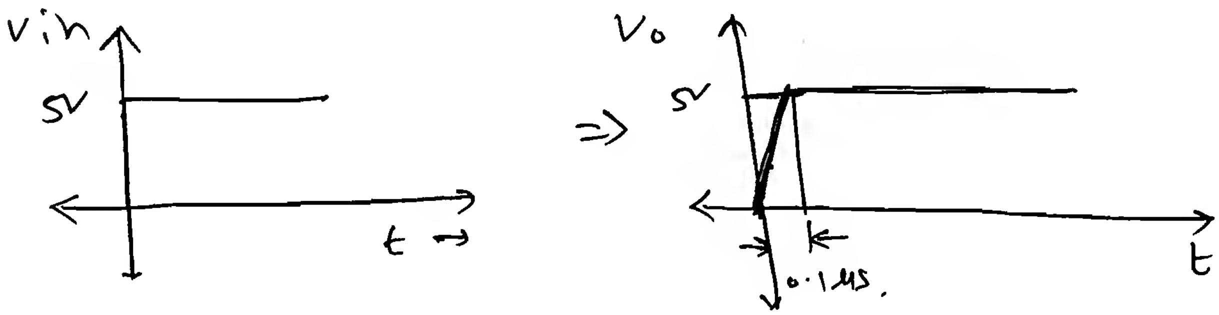




(i/p) (O/P)

$$\therefore \text{Slew rate} = \frac{5V}{0.1\mu se} = 50 \ V/\mu sec.$$

→ Step signal is a test signal to measure slew rate of an op-Amp.



→ What is $|SR|_{signal}$.

→ $V_o = V_m \sin\omega t$.

$\therefore \dfrac{dV_o}{dt} = \omega V_m \cos\omega t$.

$\therefore \left|\dfrac{dV_o}{dt}\right|_{max} = \omega V_m$.

$\therefore$ Slew Rate $= |SR| = \left|\dfrac{dV_o}{dt}\right|_{max} = \omega V_m$.

$$\therefore \boxed{SR = 2\pi f_{max} \cdot V_{omax}.}$$

Ex-(1): An op-Amp has a slewrate of $1V/\mu s$. with gain of 40 dB. If this amplifier has to faithfully amplify sinusoidal signals from 0 to 20 KHZ without any distortion. What must be the max. input signal level.

Ans:

$|SR| = 2\pi f_{max} \times V_{omax}$.

$\therefore V_{omax} = \dfrac{SR}{2\pi f_{max}}$.

$= \dfrac{1}{2 \times \pi \times 20 \times 10^3 \times 10^{-6}}$.

$\therefore V_{omax} = \dfrac{1000}{40\pi}$

$$\therefore \boxed{V_{omax} = 7.95V}$$

$$\rightarrow \quad gain_{dB} = 20 \log \left| \frac{V_{omax}}{V_{imax}} \right|.$$

$$\therefore \quad \cancel{40}^{2} = \cancel{20} \log \left| \frac{7.95}{V_{imax}} \right|.$$

$$\therefore \quad 100 = \frac{7.95}{V_{imax}}.$$

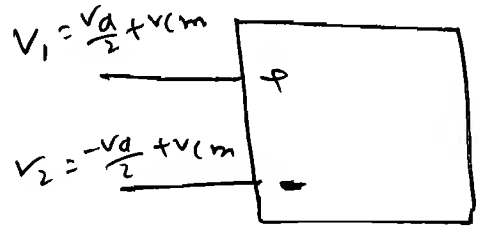
$$\therefore \quad \boxed{V_{imax} = 79.5\,mV.}$$

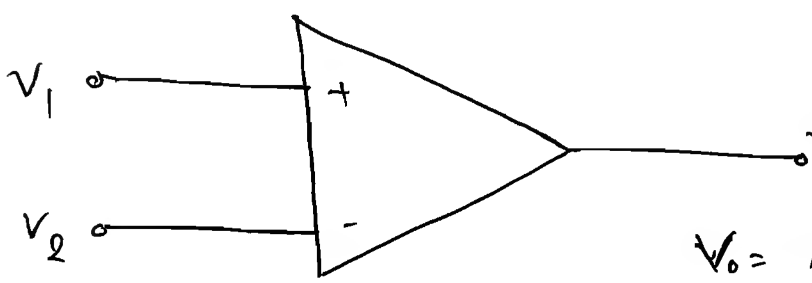
★ **CMRR : Common Mode Rejection ratio:**

→ It is a Ratio of differential Mode gain to the Common mode gain.

$$\boxed{CMRR = \left| \frac{A_d}{A_{cm}} \right|}$$

Ideally $\boxed{A_{cm} = 0.}$ & $\boxed{CMRR = \infty.}$





$V_o = A[V_1 - V_2]$

$V_o = \underbrace{A_d V_d}_{} + \underbrace{A_{cm} . V_{cm}.}_{error}$

$$\rightarrow \quad V_o = A(V_1 - V_2).$$

$$V_o = A_d V_d + A_{cm} . V_{cm}.$$

$$\therefore \quad V_o = A_d V_d \left[1 + \frac{A_{cm} \cdot V_{cm}}{A_d \cdot V_d} \right]$$

$\therefore$ in worst case $V_{cm} = V_d$.

$$\therefore \quad V_o = A_d V_d \left[1 + \frac{A_{cm}}{A_d} \right].$$

But $CMRR = \left| \frac{A_d}{A_{cm}} \right|$.

$\therefore$ ~~$V_o = A_d V_d [1 + \ldots$~~

$$\therefore \quad CMRR = \left| \frac{A_d}{A_{cm}} \right|.$$

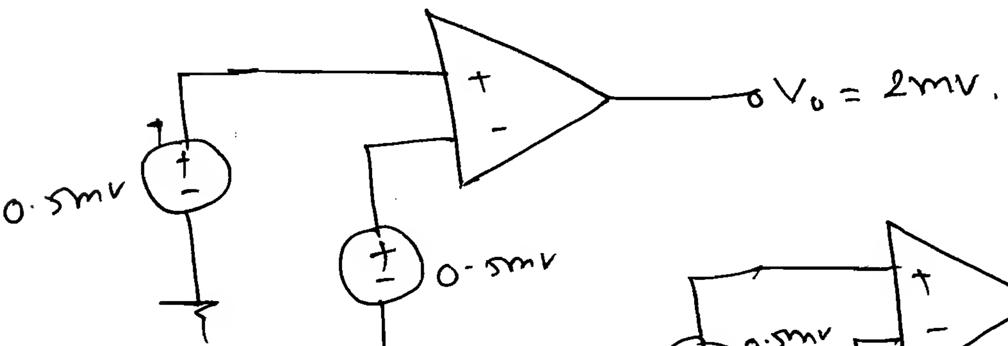
$$\therefore \quad CMRR_{dB} = 20 \log \frac{A_d}{A_{cm}}.$$

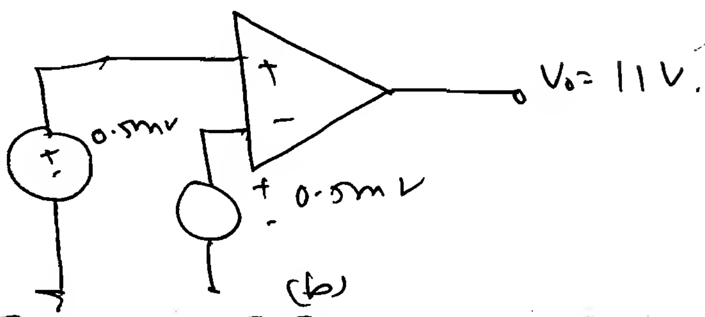
$$\therefore \quad \boxed{\frac{A_d}{A_{cm}} = 10^{\frac{CMRR_{dB}}{20}}}$$

$$\therefore \quad \boxed{V_o = A_d V_d \left[1 + \frac{1}{10^{\frac{CMRR_{dB}}{20}}} \right]}$$

→ error < 0.1%.

Ex-1 Calculate CMRR.





Ans: $A_d = \frac{V_o}{V_d} = \frac{11V}{0.5m-(0.5m)}$

$\therefore A_d = \frac{11}{1\times10^{-3}}$

$\therefore \boxed{A_d = 11000}$

from - figure - a

$\Rightarrow A_{cm} = \frac{V_o}{V_{cm}}$

$A_{cm} = \frac{2mV}{0.5mV} = 4.$

$\therefore CMRR = \frac{A_d}{A_{cm}}.$

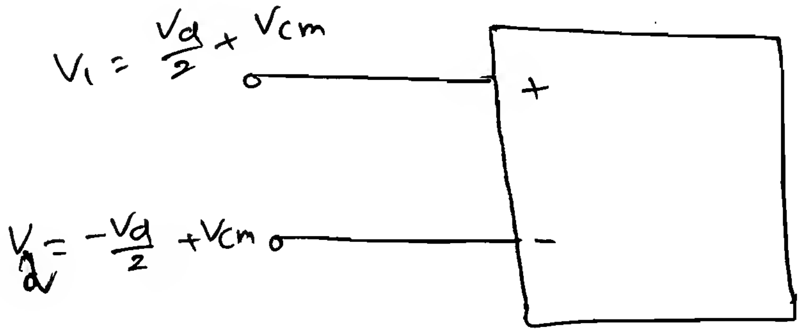
$\therefore CMRR = \frac{11000}{4} = 2750$

$\therefore CMRR_{dB} = 20 \log \left| \frac{A_d}{A_{cm}} \right|$

$= 20 \log \left| \frac{11000}{4} \right|$

$\therefore \boxed{CMRR = 68.7 \text{ dB}}$

*



$V_d = V_1 - V_2$

$V_{cm} = \frac{V_1 + V_2}{2}.$

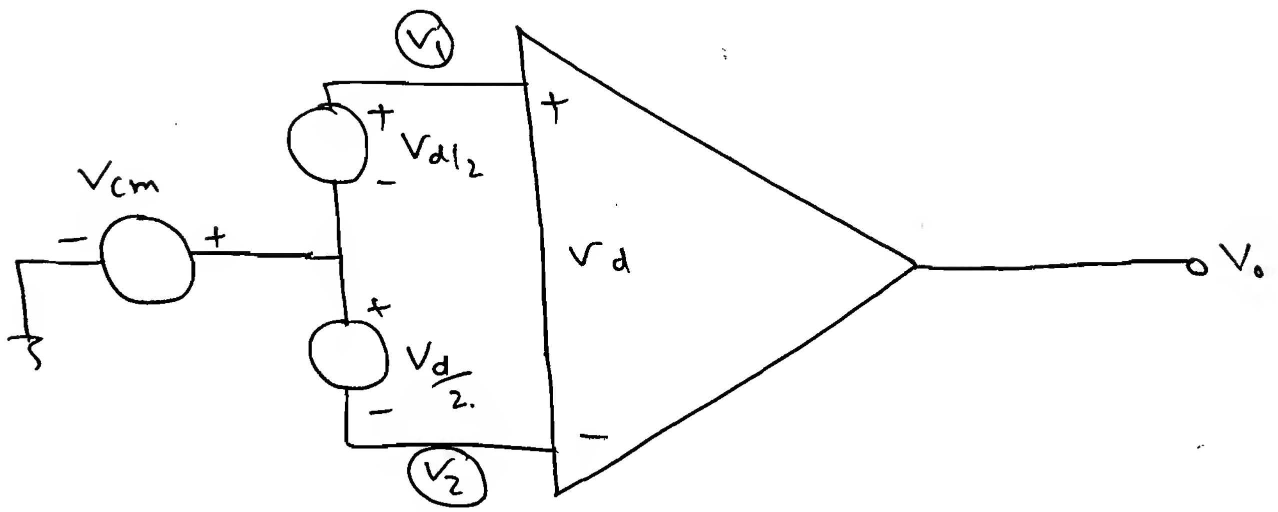
$$\rightarrow \quad V_1 = \underbrace{\frac{V_1}{2} + \frac{V_2}{2}}_{} + \underbrace{\frac{V_1}{2} - \frac{V_2}{2}}_{}.$$

$$V_1 = V_{cm} + \frac{V_d}{2}.$$

$$\rightarrow \quad V_2 = \frac{V_2}{2} + \frac{V_1}{2} + \frac{V_2}{2} - \frac{V_1}{2}.$$

$$V_2 = V_{cm} + \left(-\frac{V_d}{2}\right).$$

$$\therefore V_2 = V_{cm} - \frac{V_d}{2}.$$



* Supperposition:

$$V_o = A_d V_d + A_{cm}. V_{cm}$$

$$V_o = A_1 . V_1 + A_2 . V_2$$

$\therefore$ ① $V_2 = 0$, V_1 apply.

$$\therefore \quad V_o = A_1 V_1 \big|_{V_2 = 0} \Rightarrow A_1 = \frac{V_o}{V_1}.$$

② $V_1 = 0$, V_2 apply.

$$\therefore \quad V_o = A_2 V_2 \big|_{V_1 = 0} \Rightarrow A_2 = \frac{V_o}{V_2}.$$

$$\therefore \quad V_o = A_d V_d\Big|_{V_{cm}=0} + A_{cm} V_{cm}\Big|_{V_d=0}$$

$$= A_1 V_1\Big|_{V_2=0} + A_2 V_2\Big|_{V_2=0}$$

$$\therefore \quad A_d = \frac{A_1 - A_2}{2}$$

$$\boxed{\begin{aligned} &* \ A_{cm} = A_1 + A_2. \\ &\therefore * \ CMRR = \frac{A_d}{A_{cm}}. \\ &\therefore * \ CMRR = \frac{A_1 - A_2}{2(A_1 + A_2)} \end{aligned}}$$

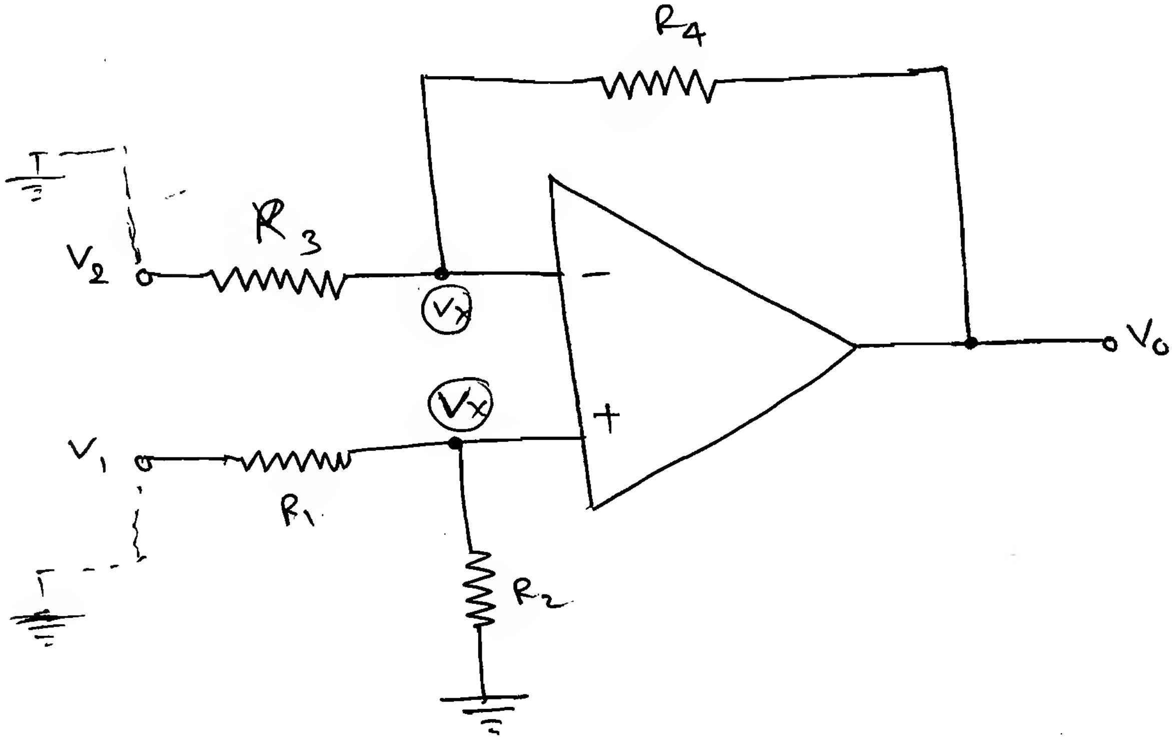
$$A_{cm} = \frac{2A_1 \cdot A_2}{A_1 + A_2}.$$

$$A_d = \frac{A_1 \cdot A_2}{A_2 - A_1}.$$

$$CMRR = \frac{A_1 + A_2}{2(A_2 - A_1)}.$$

☆ CMRR of Difference amplifier:-

$\Rightarrow$



→ By supper possition

$$\therefore \quad A_1 = \frac{V_o}{V_1}\Big|_{V_2=0}, \qquad A_2 = \frac{V_o}{V_2}\Big|_{V_1=0}.$$

— (i) when $V_2 = 0$.

$$\therefore \quad V_x = \left(\frac{R_2}{R_1+R_2}\right) V_1.$$

$$\therefore \quad V_o = \left(1 + \frac{R_4}{R_3}\right) V_x.$$

$$\therefore \quad V_o = \left(1 + \frac{R_4}{R_3}\right) \times \left(\frac{R_2}{R_1+R_2}\right) V_1.$$

$$\therefore \quad A_1 = \frac{V_o}{V_1} = \frac{(R_3+R_4)\, R_2}{R_3\,(R_1+R_2)}.$$

(ii) when $V_1 = 0$.

$$\therefore \quad V_o = -\left(\frac{R_4}{R_3}\right) V_2.$$

$$\Rightarrow \quad A_2 = \frac{V_o}{V_2} = \frac{\cancel{A_1 - A_2}}{\cancel{2(A_1 + A_2)}} \cdot \quad -\frac{R_4}{R_3}$$

$\Rightarrow$ CMRR $= \infty$ when $A_{cm} = 0 = A_1 + A_2 = 0$.

$$\therefore \quad A_1 = -A_2. \qquad \text{CMRR} = \frac{A_1 - A_2}{2(A_1+A_2)}.$$

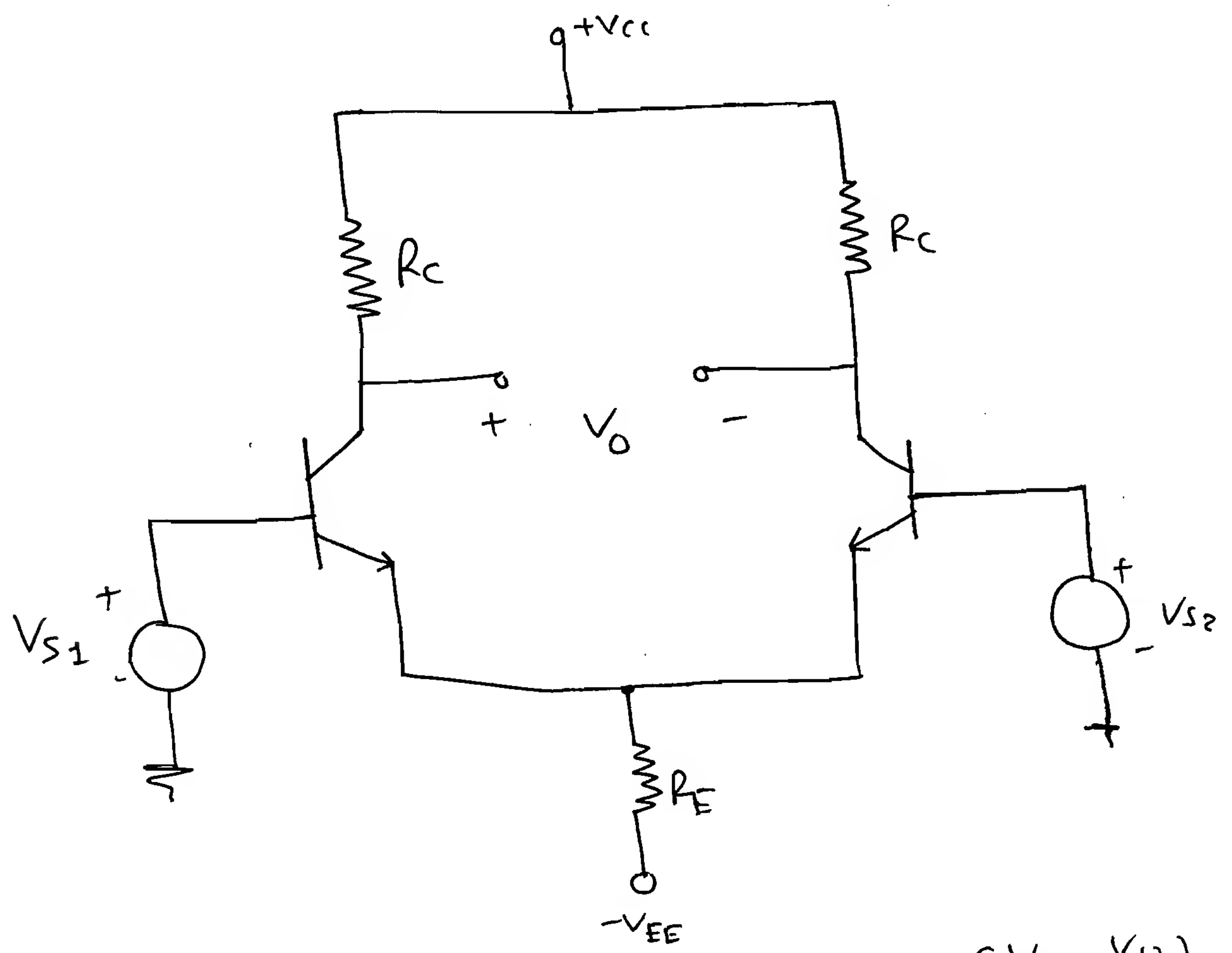
$$\therefore \quad \frac{R_4}{\cancel{R_3}} = \frac{(R_3+R_4)\, R_2}{\cancel{R_3}\,(R_1+R_2)}$$

$$\therefore \quad \frac{R_1+R_2}{R_2} = \frac{R_3+R_4}{R_4}.$$

$$\therefore \quad \cancel{1} + \frac{R_1}{R_2} = \cancel{1} + \frac{R_3}{R_4}.$$

$$\therefore \quad \boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

★ CMRR For a Differential Amplifier:



$V_o = K(V_{s1} - V_{s2})$

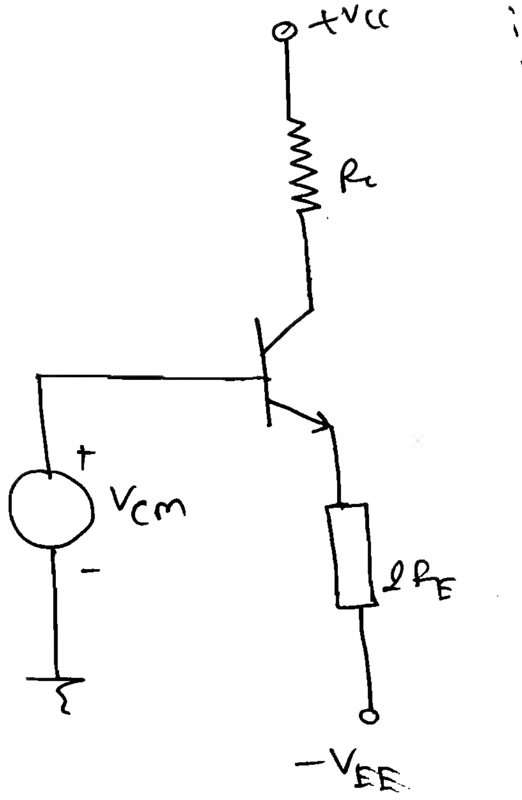
$V_o = K_1 V_{s1} - K_2 V_{s2}.$

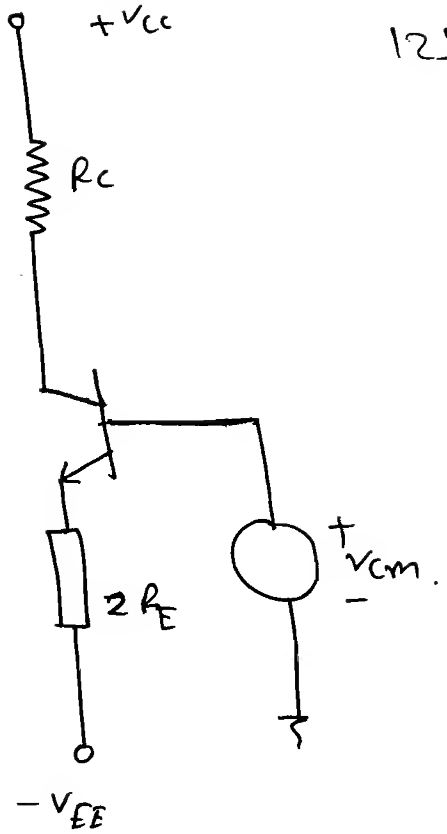
$\therefore \Rightarrow V_o = -g_m R_c [V_{s1} - V_{s2}].$

$\Rightarrow$ Differential gain $= A_d = \frac{V_o}{V_d} = \frac{V_o}{V_{s1} - V_{s2}} = -g_m R_c.$

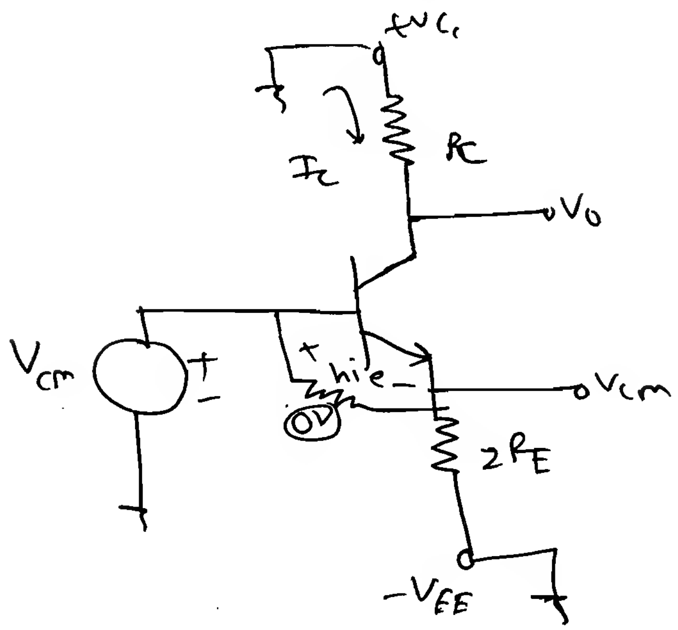
→ If $V_{s1} = V_{s2}$, $V_o = 0$, this is under the assumption that both transistor have the same AC char. which is not possible. Hence we go for single ended Analysis to make the individual gains as low as possible such that the difference can still be zero due to common signals.

=>





=> For AC analysis



negalte hie

=> hie = 0.

$\therefore \boxed{V_{cm} = V_E}$ ±/V_e.

$\therefore \quad V_o = -I_c R_c$.

$\therefore \quad I_c = I_E = \frac{V_E}{2R_E} = \frac{V_{cm}}{2R_E}$.

$\therefore \quad V_o = -\frac{V_{cm}}{2R_E} \cdot R_c$.

$\therefore \quad \frac{V_o}{V_{cm}} = \frac{-R_E}{2R_c}$.

$$\therefore \boxed{A_{cm\,(\text{half ckt})} = -\frac{R_C}{2R_E}}$$

$$\therefore \quad CMRR = \frac{A_d}{A_{cm}}$$

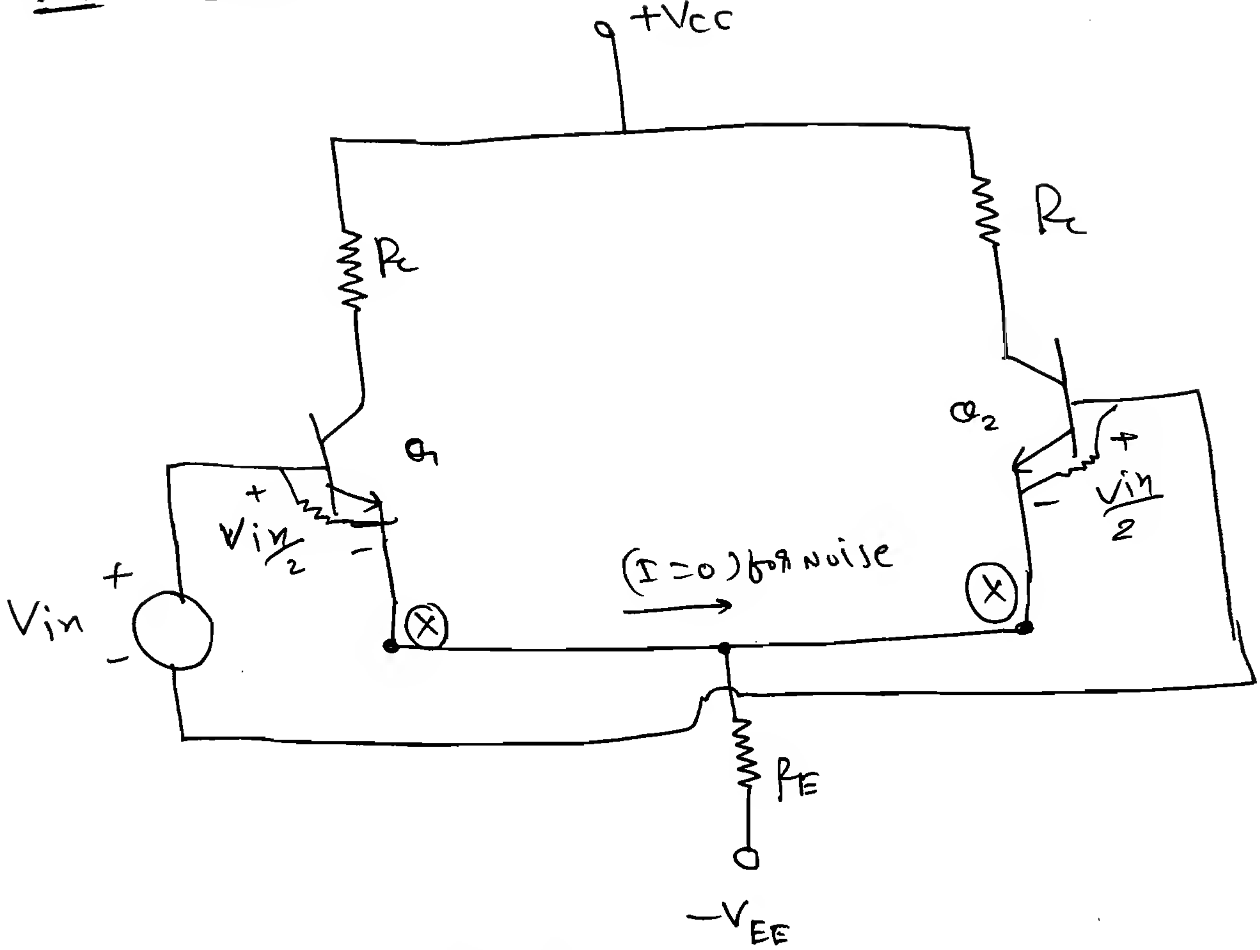
$$= \frac{-\frac{g_m R_C}{2}}{-R_C/2R_E}$$

$$\therefore \boxed{CMRR = +g_m R_E}$$

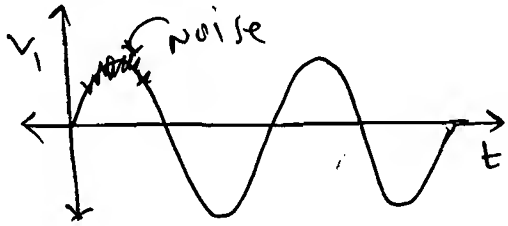
→ CMRR can be improved by increasing R_E hence Replace R_E with a constant current source (or) current mirror. Current mirrors offers large o/p impedence improving CMRR.

*** Imp Concept:**

→

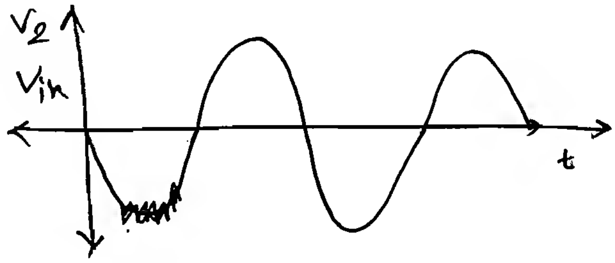


→ Input at Q1:



$= \frac{V_{in}}{2} + N.$

→ Input at Q2:



$= -\frac{V_{in}}{2} + N.$

⇒ change in input signal at Q1 & Q2 are ~~...~~ different (i.e. 180 phase shift i.e $\frac{V_{in}}{2}$ & $-\frac{V_{in}}{2}$).

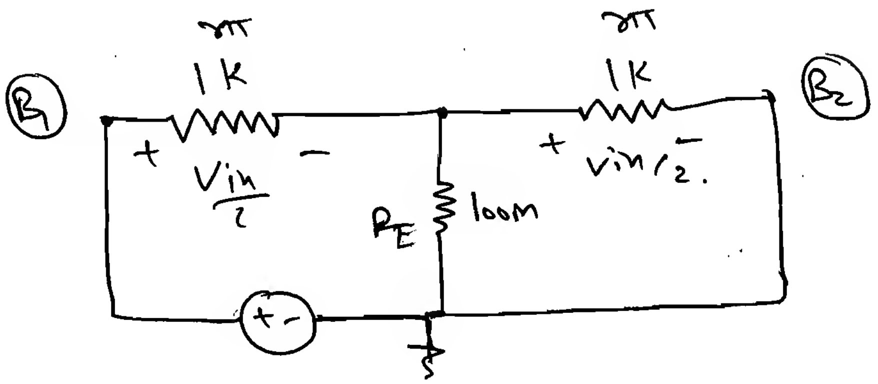
But change in the Noise is same at input at Q1 & Q2.

① Now, there are no noise.

∴ Change in the signal is different.

hence Voltage at ~~ba~~ node ⓧ are different i.e. $V_{in}/2$ & $-V_{in}/2$.

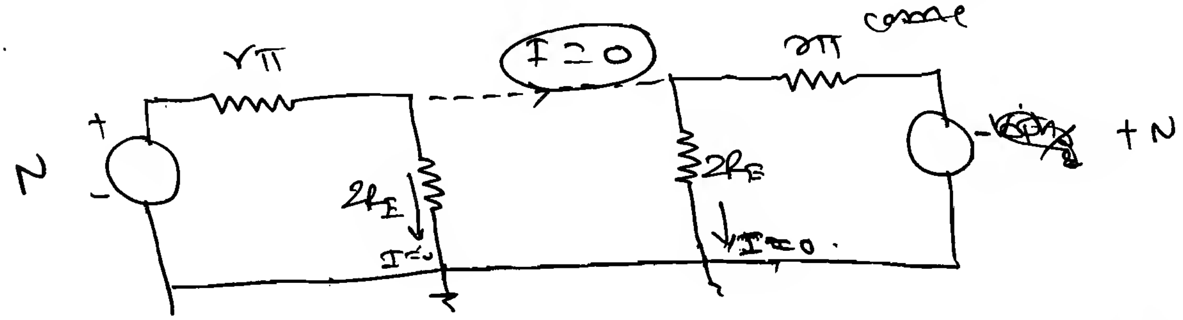
for A.C.



→ R_E is very large. So, it is treated at O.C. and R_E is dumy when there is no noise.

② But, Now as Noise entere into the signal then Change in the noise at both input are same. therefore Voltage at ⓧ & ⓧ are same due to noise. ~~Structure split into two part when noise~~ come

i.e.



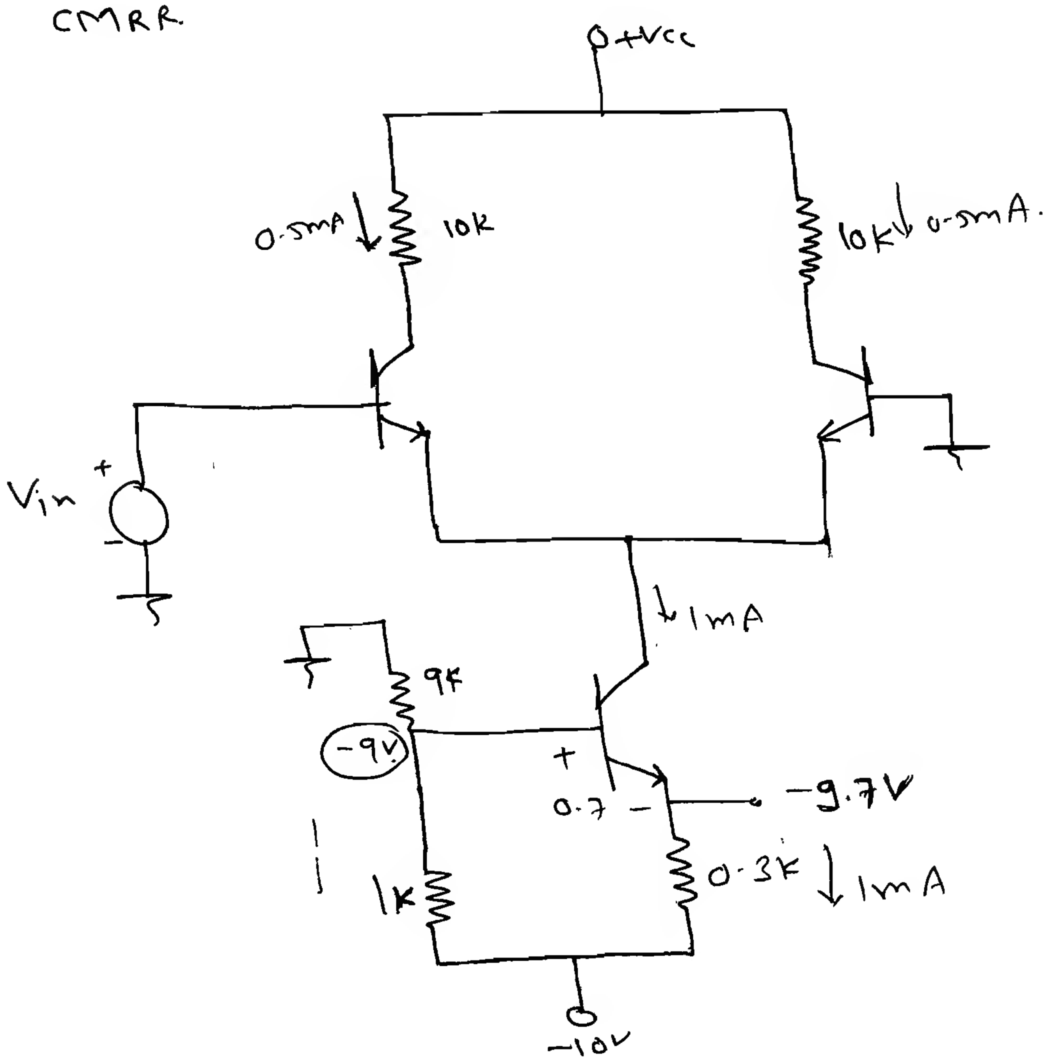
⇒ So, Noise at both end nailed to the ground through R_E. i.e. noise are get Cancelled out.

* Beauty of Differential amplifier:

⇒ As the desired signal is comming then it act as double ended structure.

⇒ But as soon as Noise come, it split into two parts nicely, for noise and noises are nailed to ground through R_E.

Ex-1 A Common mode gain is 0.001, calculate CMRR.



→ $A_d = \frac{+g_m \cdot R_c}{2}$

$g_m = \frac{I_{C_{DC}}}{\beta V_T}$

$= \frac{0.5m}{25m} = \frac{1}{50}$

$\therefore A_d = \frac{\frac{1}{50} \times 10k}{2} = -100.$

$CMRR = \left|\frac{A_d}{A_{cm}}\right|$

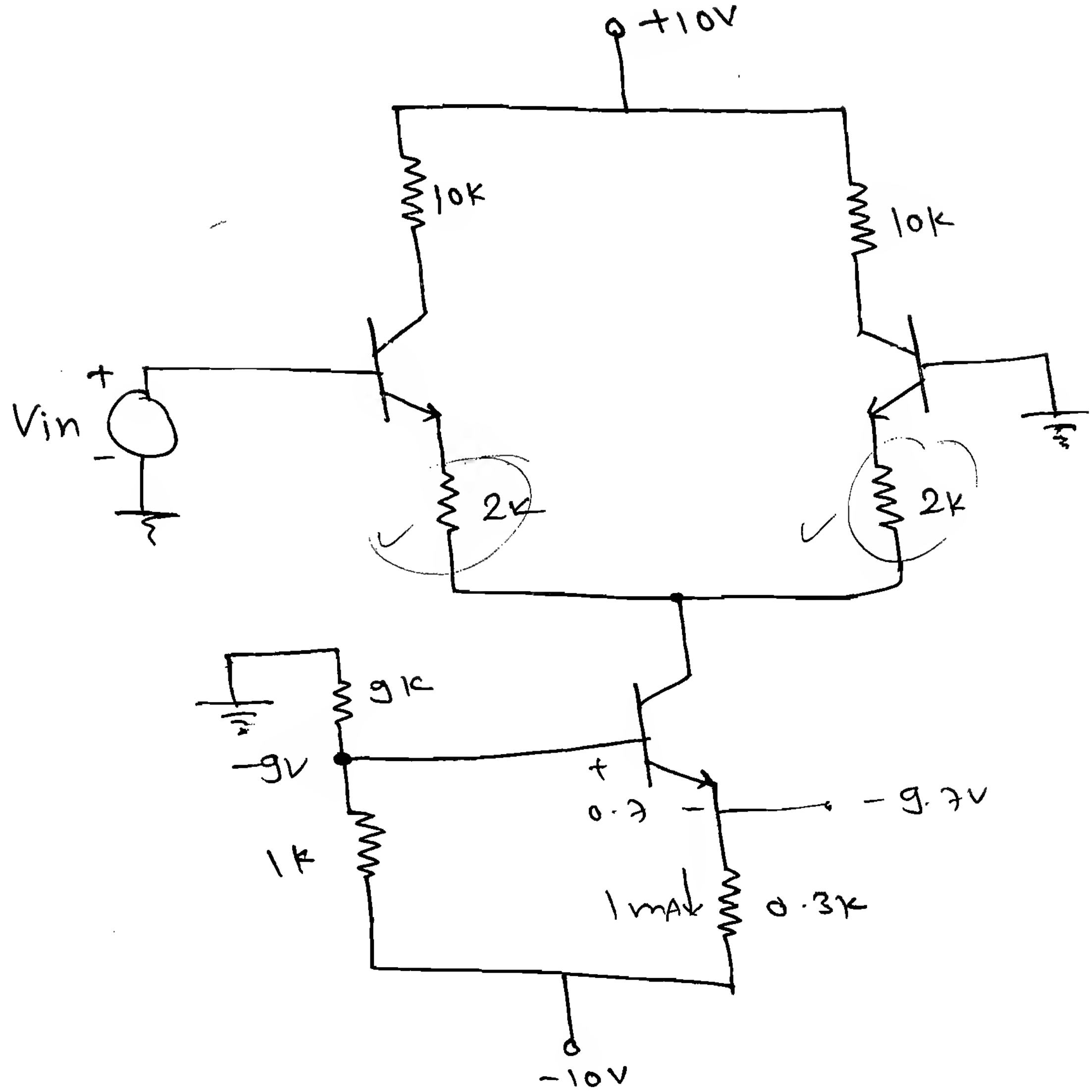
$= \left|\frac{100}{0.01}\right|$

$\therefore$ CMRR = 10^5.

$\therefore$ $CMRR_{dB} = 20 \log 10^5 = 100\,dB$

$\therefore$ $\boxed{CMRR = 100\,dB}$

Ex-2 Find CMRR:



given $A_{cm} = 0.001$.

$\therefore$ $A_d = -\frac{R_C}{R_E}$

But CMRR is calculated for half ckt.

$\therefore$ $A_d = \frac{-R_C}{\frac{2R_E}{2}} = \frac{-10K}{\frac{4K}{1}} = -2.5$.

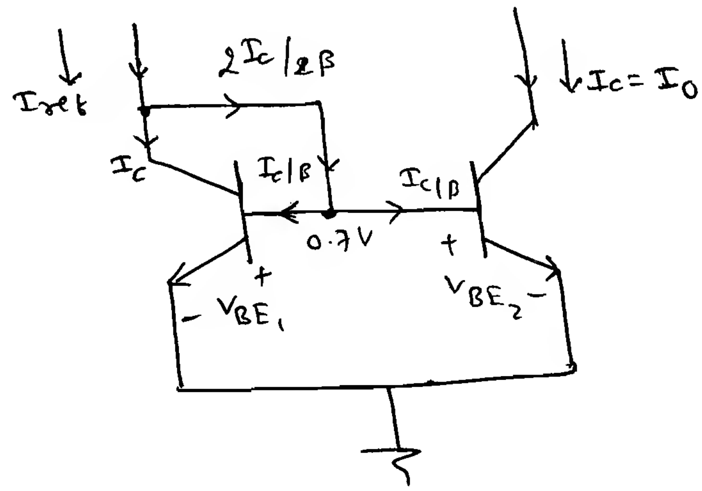
$$\therefore \quad CMRR = \left| \frac{2.5}{0.001} \right| = 2500.$$

$$\therefore \quad CMRR = 20\log_{10} 2500$$

$$\therefore \quad \boxed{CMRR = 67.96\ dB}$$

☆ Current Mirror:

→



→ By KCL,

$$I_{ref} = I_c + 2\frac{I_c}{2\beta}.$$

$$I_{ref} = I_c \left[1 + \frac{2}{2\beta} \right]$$

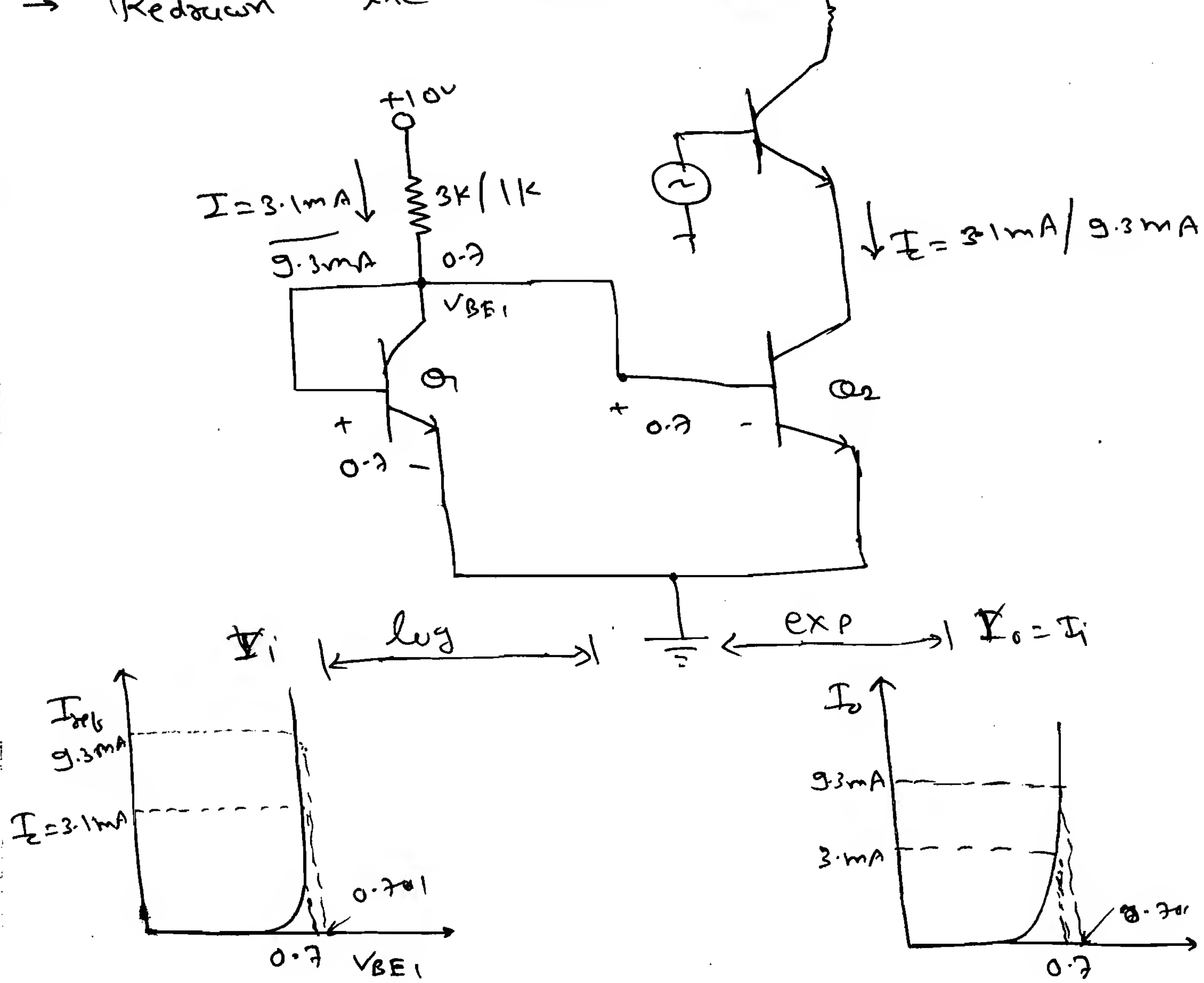
$$\therefore \quad I_{ref} = I_o \left[1 + \frac{2}{2\beta} \right]$$

if β is very large.

$$\therefore \quad \boxed{I_{ref} \approx I_o}$$

By giving I_{ref} we can control or set I_o.

→ Redrawn the current mirror:



NOTE: if current changes the voltage it is log operation, and if voltage changes the current it is exponential operation.

→ $$I_c = I_s \cdot e^{\frac{V_{BE}}{V_T}}.$$

$$\therefore V_{BE_1} = V_T \log\left(\frac{I_{c_1}}{I_s}\right) \quad (\log).$$

$\because$ But $V_{BE_1} = V_{BE_2}$.

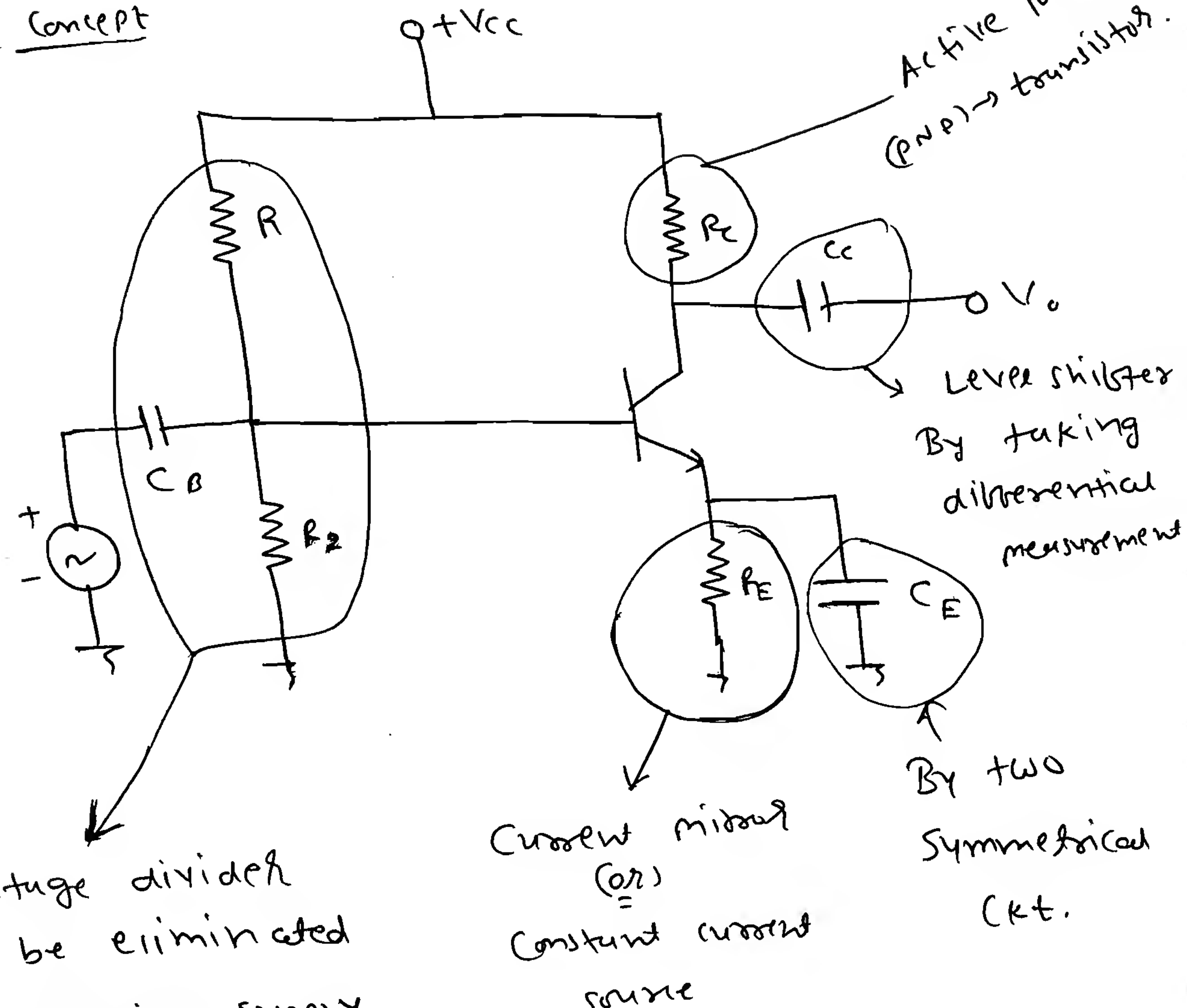
$$\therefore I_{c2} = I_s \cdot e^{V_{BE_2}/V_T}.$$

$$\therefore \quad I_{C2} = I_S \cdot e^{\frac{V_{BE1}}{V_t}}$$

$$\therefore \quad \boxed{I_{C2} = I_{C1}}$$

This current mirror:

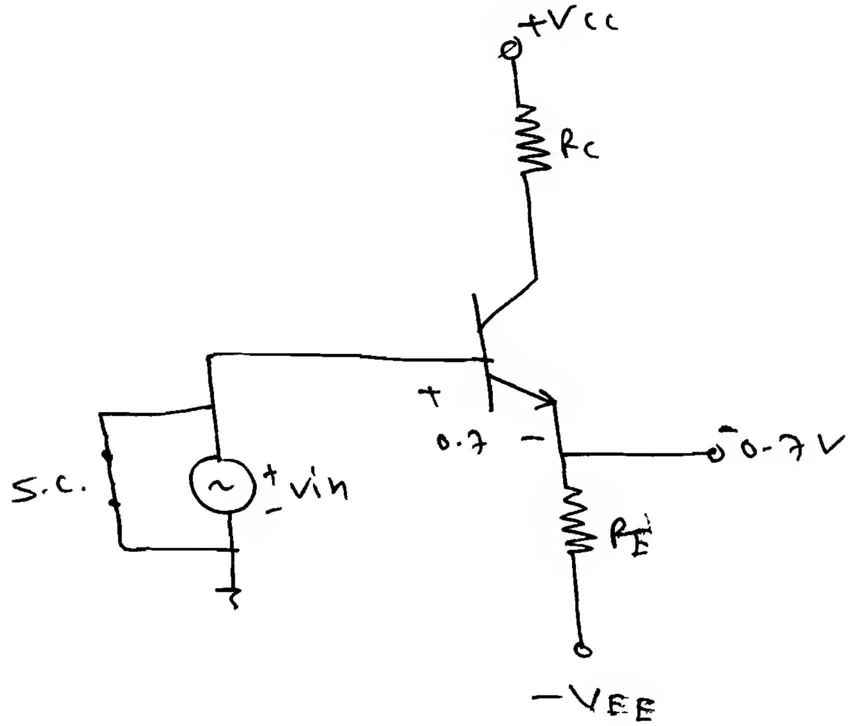
* <u>Imp Concept</u>



⇒ Voltage divider can be eliminated by Negative supply

(1) Eliminate Voltage divider By negative Supply.

DC



$$\therefore I_{C_{DC}} = \frac{-0.7 - (-V_{EE})}{R_E}$$

$$I_{C_{DC}} = \frac{V_{EE} - 0.7}{R_E}$$

$$\therefore I_{C_{DC}} = \frac{V_{EE} - V_{BE}}{R_E}$$

By voltage divider

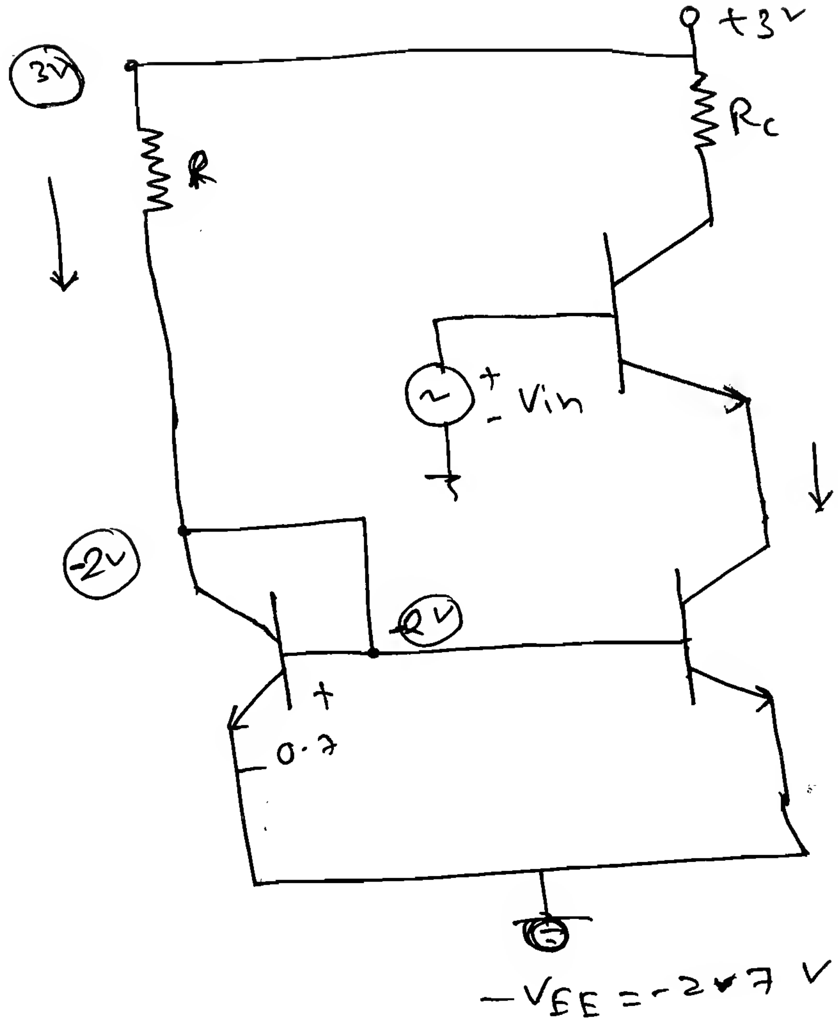
$$I_{C_{DC}} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

$$I_{C_{DC}} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

(2) We have to Replace RE By Constant current Source.

→ In absence of RE we can bias BJT with proper choise of R.

→ RE can be replaced by current mirror as shown in figure



We want 5mA
This can be achieve by choosing R..

→ Required current 5mA.

$$\therefore 5mA = \frac{3-(-2V)}{R}$$

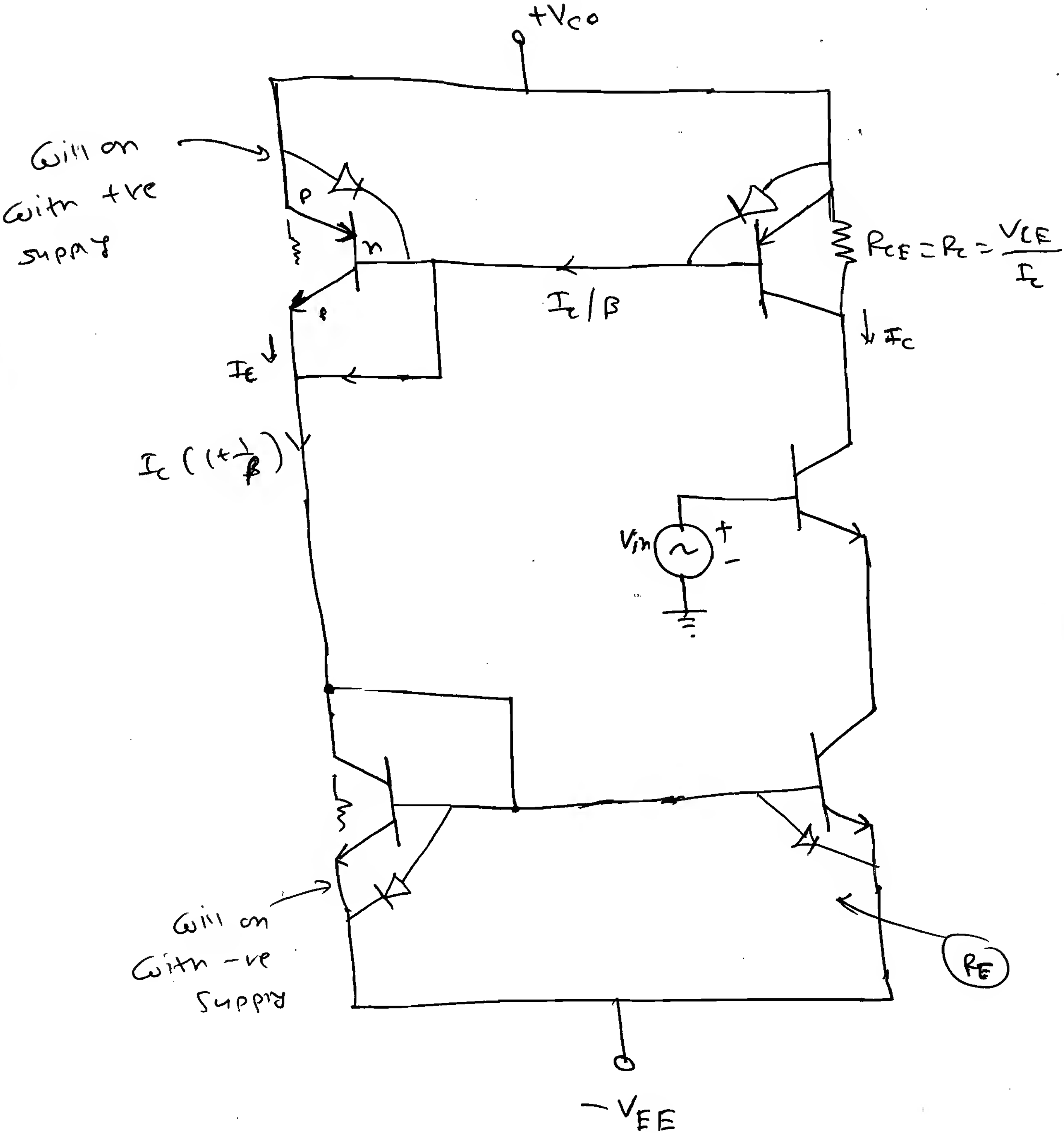
$$\therefore R = \frac{5}{5m}$$

$$\therefore \boxed{R = 1\,k\Omega}$$

→ So, Till now we replace R_1, R_2, and C_E By negative supply ($-V_{EE}$) and R_E by current mirror.

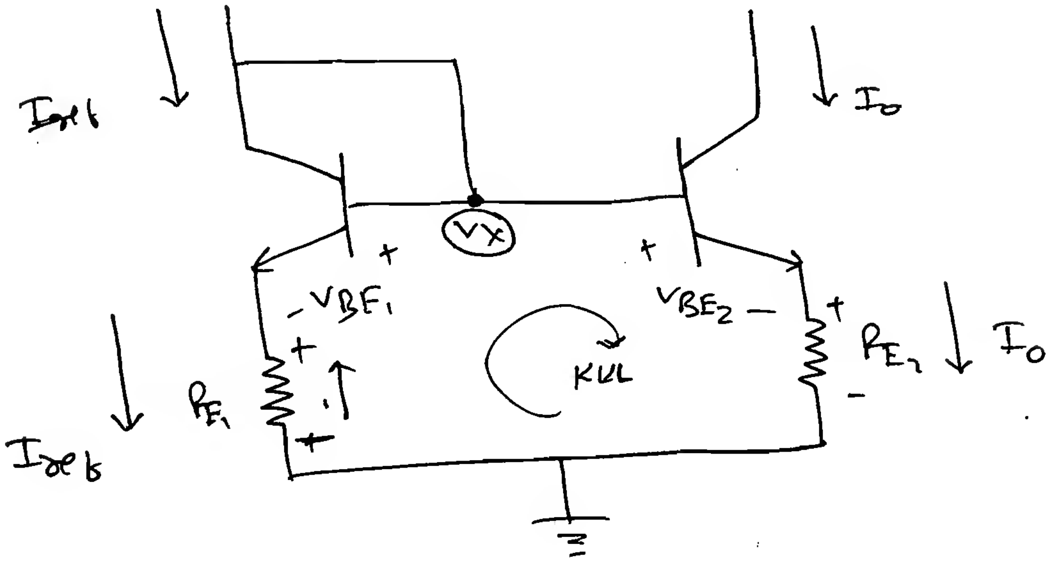
(3) Now, we can Replace R_c By PNP Transistor.

→ BJT is acting as a Resistor with Constant I_B in current mirror.



* Current mirror Emitter Degeneration Resistors:

⇒



→ $V_X = V_{BE_1} + I_{ref} R_{E_1} = V_{BE_2} + I_o R_{E_2}$.

But if $V_{BE_1} = V_{BE_2}$

$\therefore \quad I_{ref} R_{E_1} = I_o R_{E_2}$.

Idelly

$V_{BE_1} = 0.700$ L

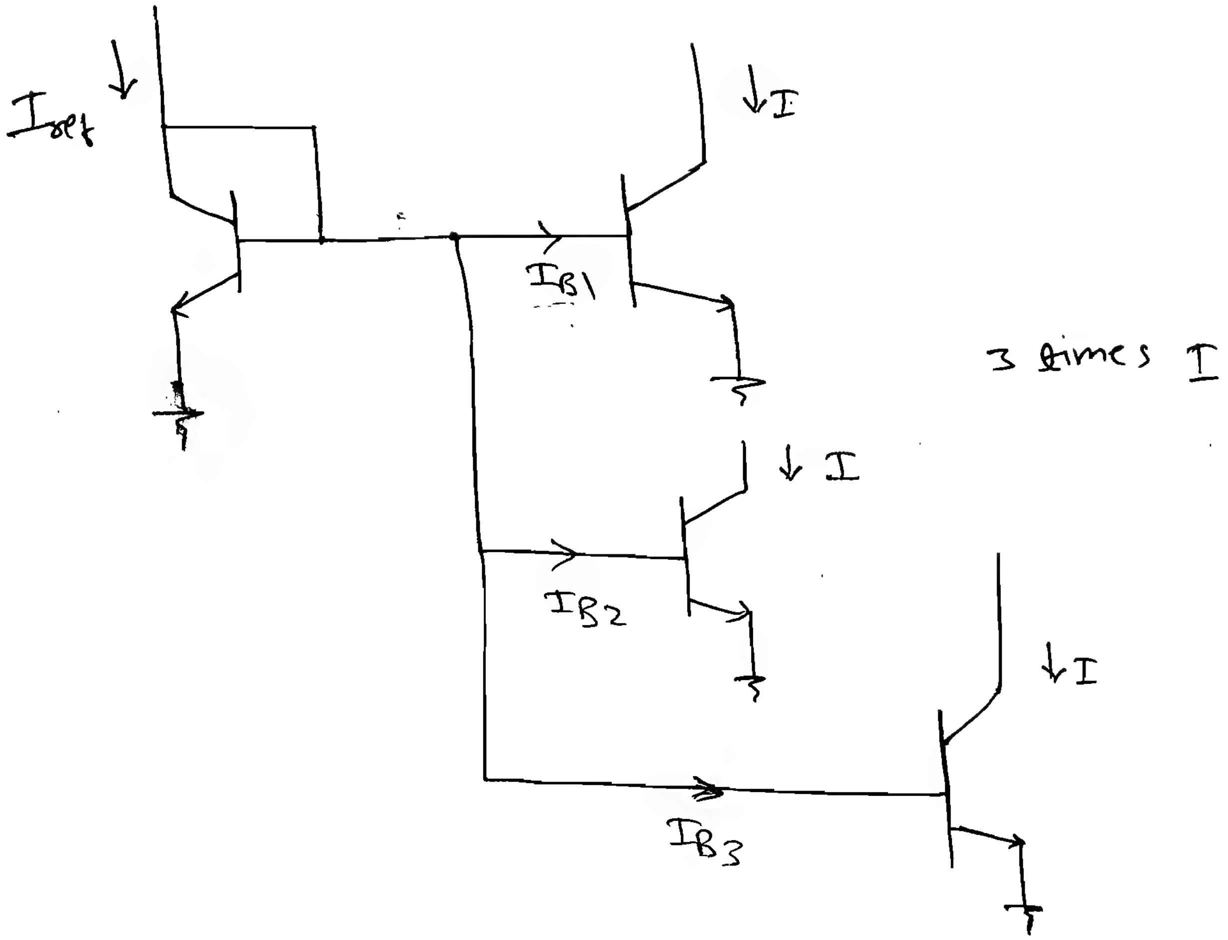
$V_{BE_2} = 0.701$ L

$$\therefore \quad \boxed{\frac{I_o}{I_{ref}} = \frac{R_{E_1}}{R_{E_2}}}$$

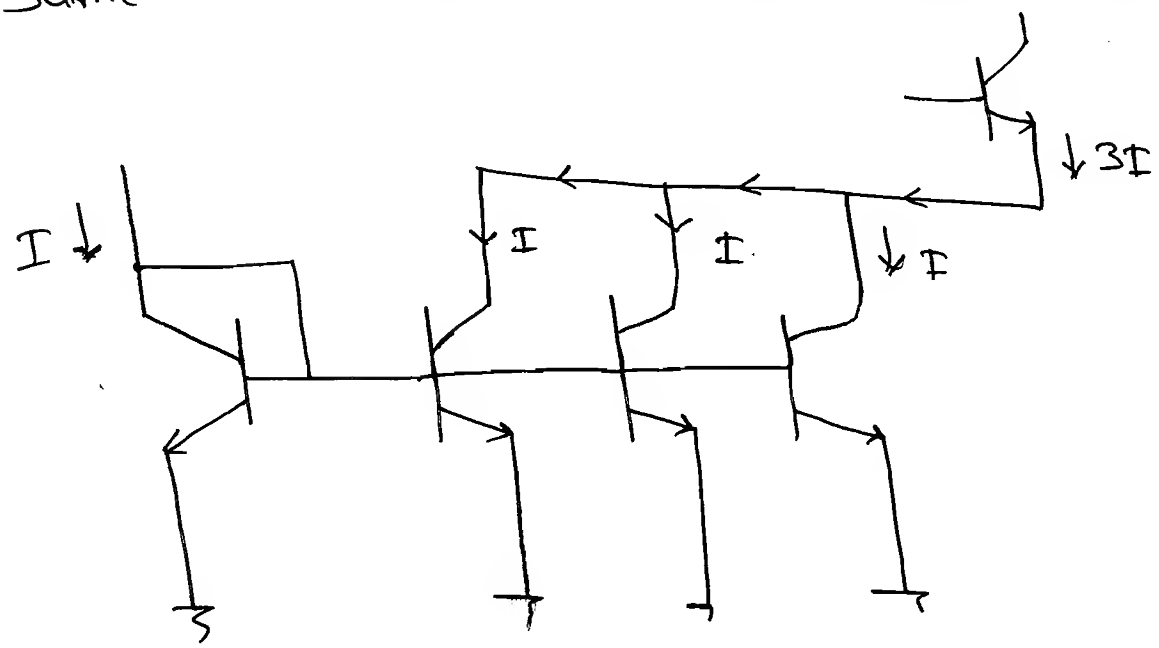
→ By choosing proper Resistor we can Adjust I_o.

☆ Current Source in Parallel :-

→



→ Same circuit can be Represented as follow:



→ Ideal output Resistance should Be ∞.

$r_o = \infty$.

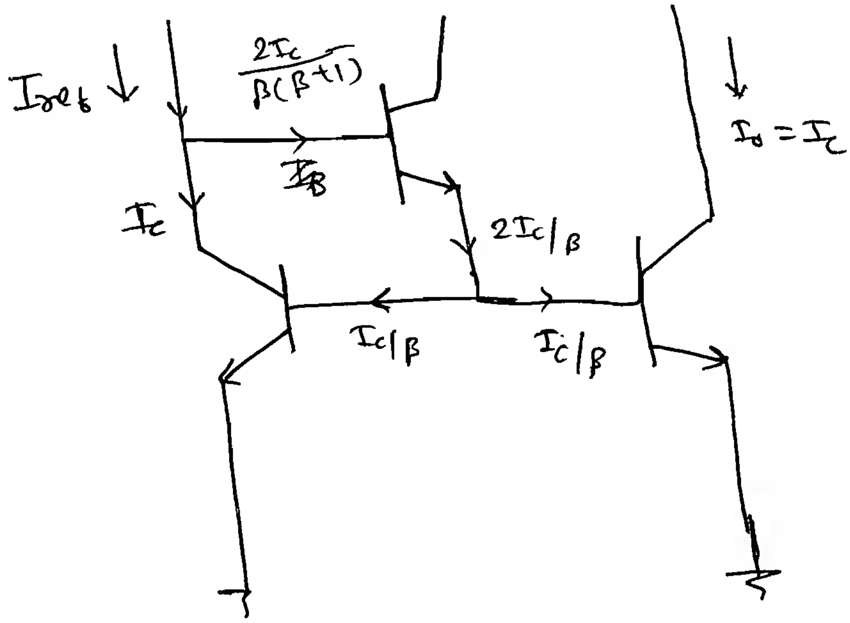
→ But as we connect current source in parallel o/p resistance will decreases.

Disadvantge:

→ The output Resistance decreases when current sources are connected in parallel.

→ The load on I_{ref} has increase to supply base currents to all the parallel transistors.

→ To decrease the load on I_{ref}. let us include transistor Q_3 in the current mirror.



$$\rightarrow \quad I_{ref} = \frac{2I_c}{\beta(\beta+1)} + I_c.$$

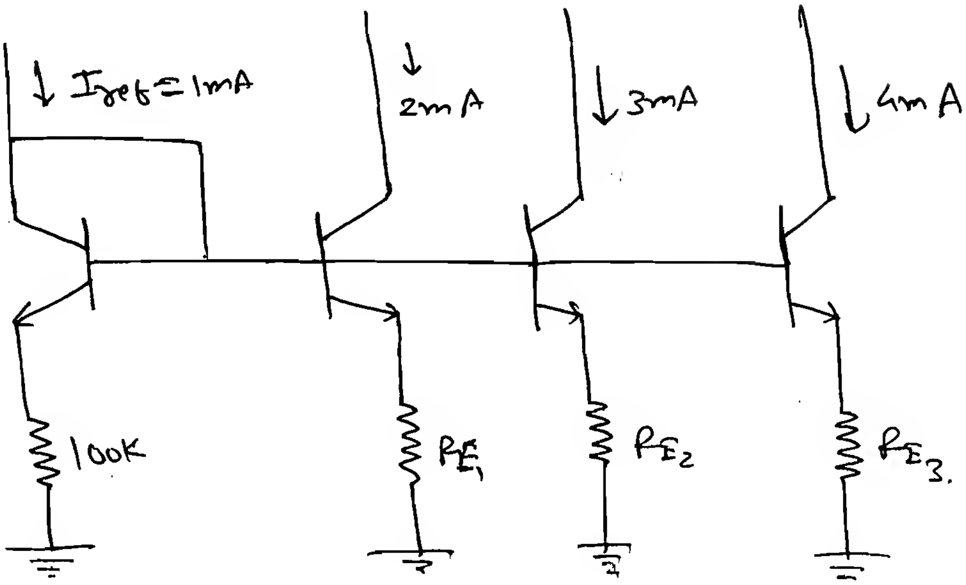
$$I_{ref} = I_c\left[1 + \frac{2}{\beta^2+\beta}\right]$$

$$\therefore \quad I_{ref} = I_o\left[1 + \frac{2}{\beta^2+\beta}\right]$$

→ If β is very large.

$\therefore$ $\boxed{I_{ref} \simeq I_o.}$

Ex-1 Find R_{E_1}, R_{E_2}, R_{E_3} ?



$\therefore$ $I_{ref} \times 100K = R_{E_1} \times 2m$

$1m \times 100K = R_{E_1} \times 2m$

$\therefore$ $\boxed{R_{E_1} = 50K}$

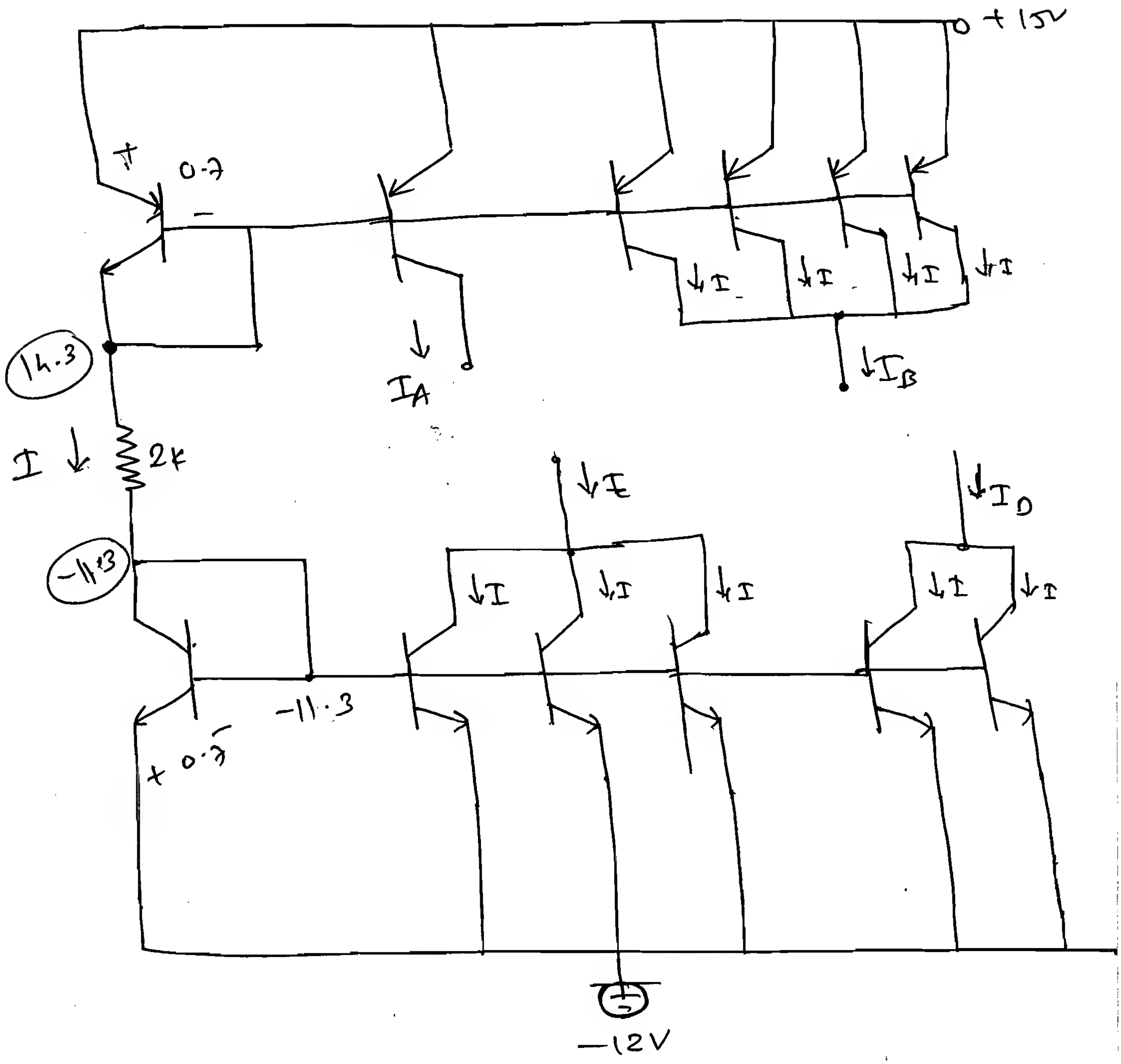
$\therefore$ $R_{E_2} = \dfrac{1m \times 100K}{3mA}$

$\therefore$ $\boxed{R_{E_2} = 33.333\ K\Omega}$

$\therefore$ $R_{E_3} = \dfrac{1m \times 100k}{4m}$

$\therefore$ $\boxed{R_{E_3} = 25\ k\Omega}$

Ex-2 Calculate I_A, I_B, I_C, I_D.



$\Rightarrow \quad I_A = I$

$I_B = 4I$

$I_C = 3I$

$I_D = 2I$

$$I = \frac{14.3 + 11.3}{2k} \text{ mA}$$

$$\boxed{I = 12.8 \text{ mA}}$$

$\therefore \boxed{I_A = 12.8 \text{ mA}}$

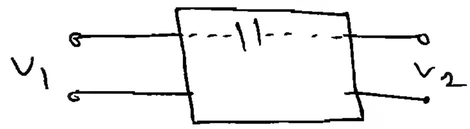
$\therefore \boxed{I_B = 12.8 \times 4 = 51.2 \text{ mA}}$

$\boxed{I_C = 3I = 12.8 \times 3 = 38.4 \text{ mA}}$

$\boxed{I_D = 2I = 25.6 \text{ mA.}}$

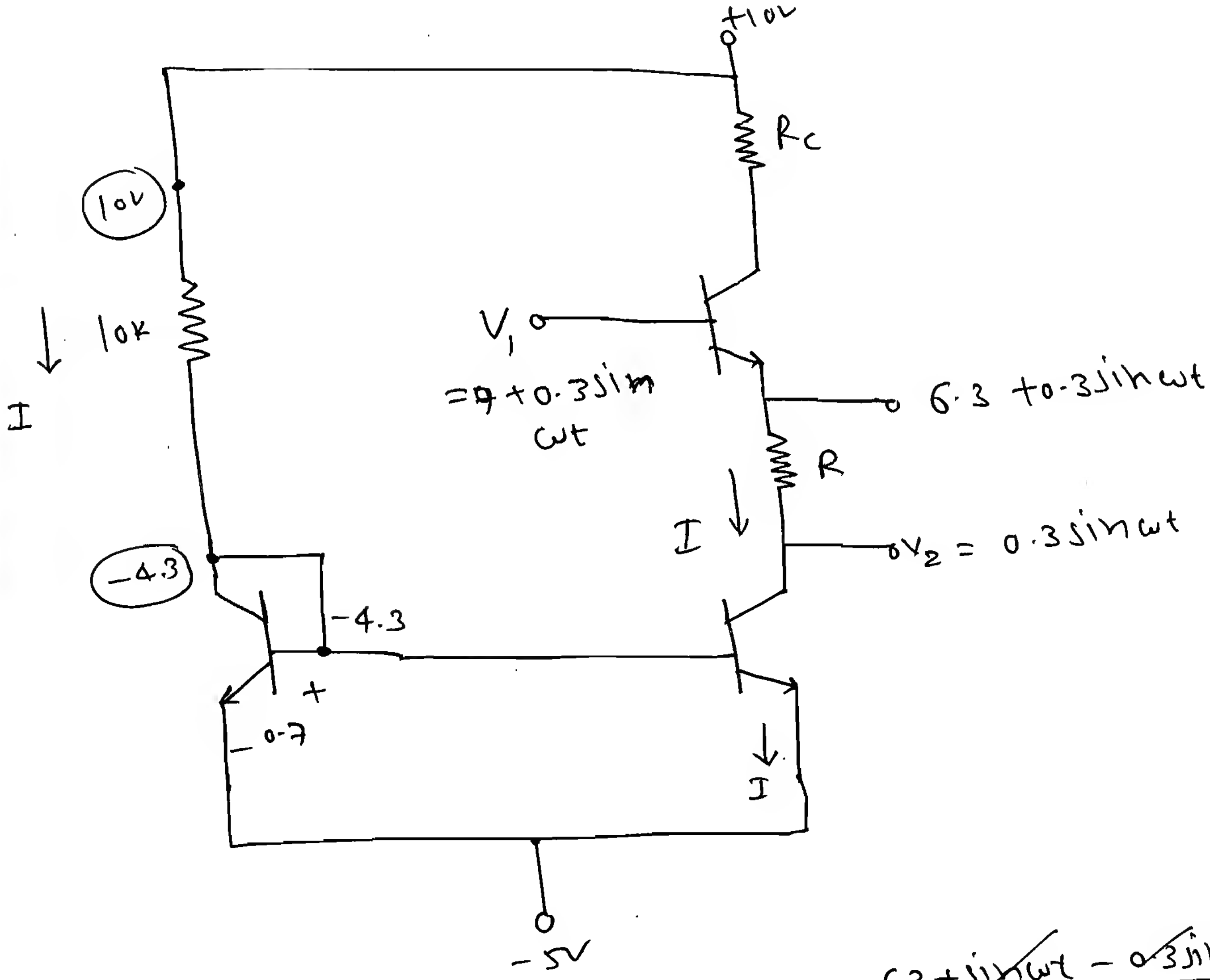
* The Purpose of the o/p capacitor : is to block Dc and allow Ac signal.

=> Dc can be Block with circuit called level shifter.



Level shifter

Ex: Find the value of R if, $V_1 = 7 + 0.3\sin\omega t$ and $V_2 = 0.3\sin\omega t$.



$\therefore I = \dfrac{10+4.3}{10k}$

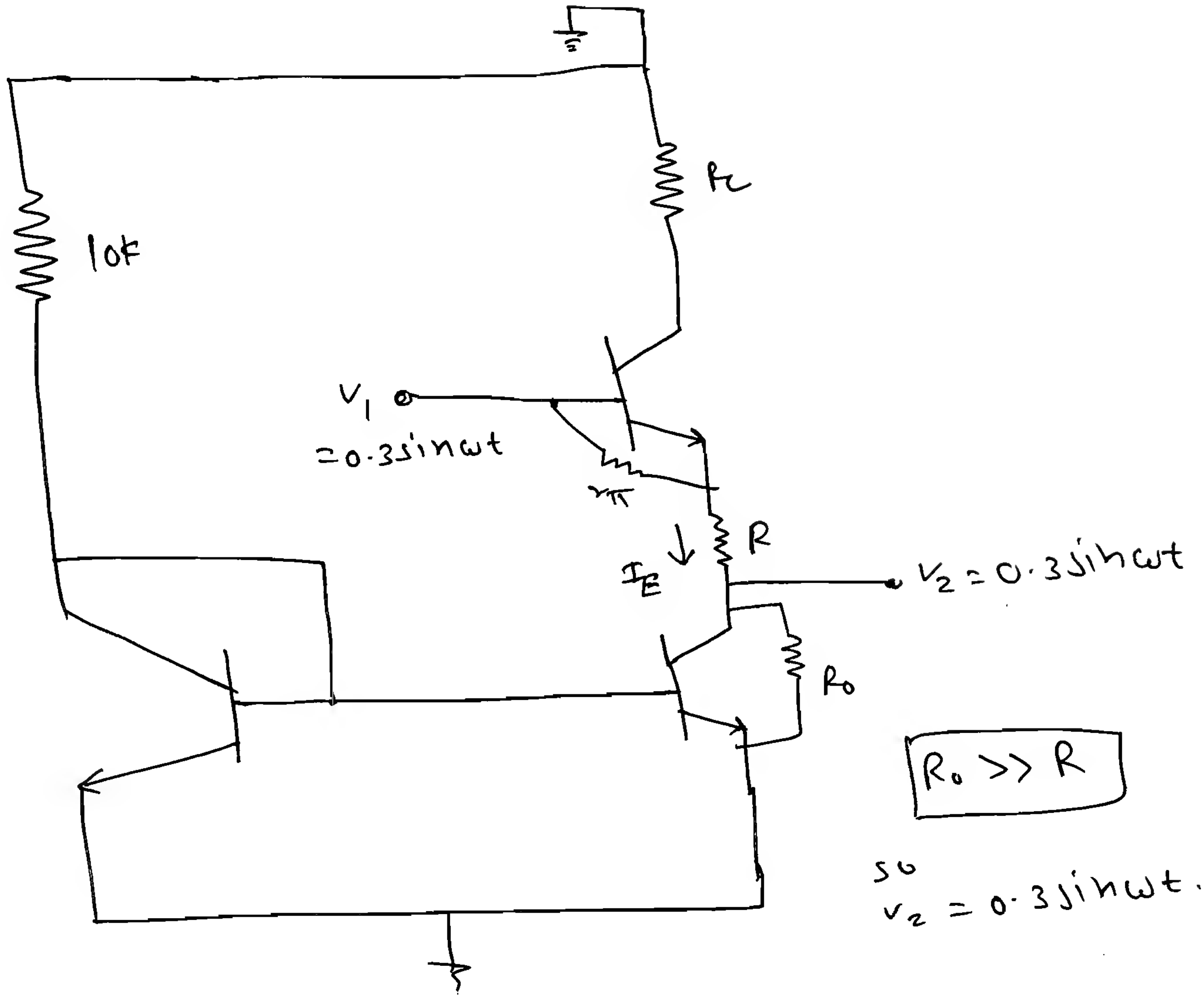
$\therefore \boxed{I = 1.43mA}$

$\therefore I = \dfrac{6.3 + \cancel{\sin\omega t} - 0.3\sin\omega t}{R}$

$\therefore R = \dfrac{6.3}{1.43}$

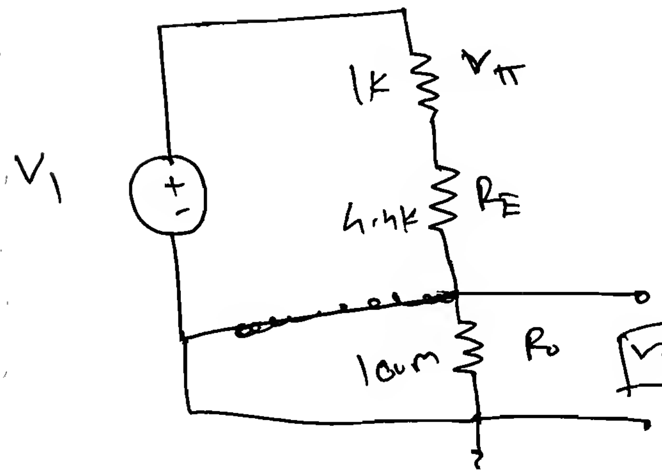
$\boxed{R = 4.4 K\Omega}$

For AC picture:

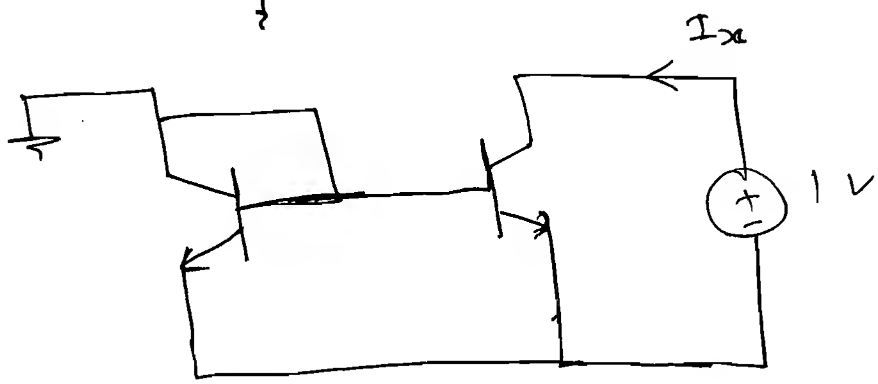


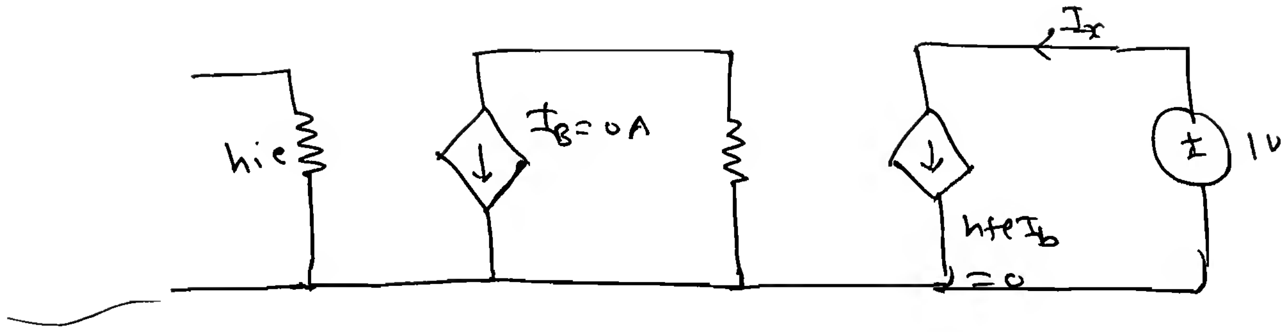
$\boxed{R_o >> R}$

so
$V_2 = 0.3\sin\omega t.$



$\boxed{V_2 \approx V_1}$





$$\Rightarrow \quad Z_o = \frac{1V}{I_x}$$

$$Z_o = \frac{1V}{0}$$

$$\boxed{Z_o = \infty}$$

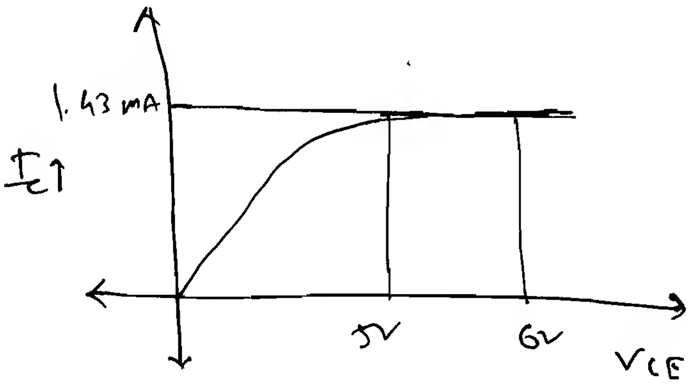
→ By BJT we can choose Resistor from 0 (sat) to ∞ (cut off) by choosing operating point. and it has versetile nature because it is non-linear

$R_E = 100\ M\Omega$

$I_{C_{DC}} = 1mA.$

$\Rightarrow$ min $V_{CC} = R_E I_{C_{DC}} = R_E I_E$

$V_{CC} = 100kV$ → Undesirable.



$$R_{DC} = \frac{5}{1.43m}$$

$R_{DC} = 3.49\ k\Omega$

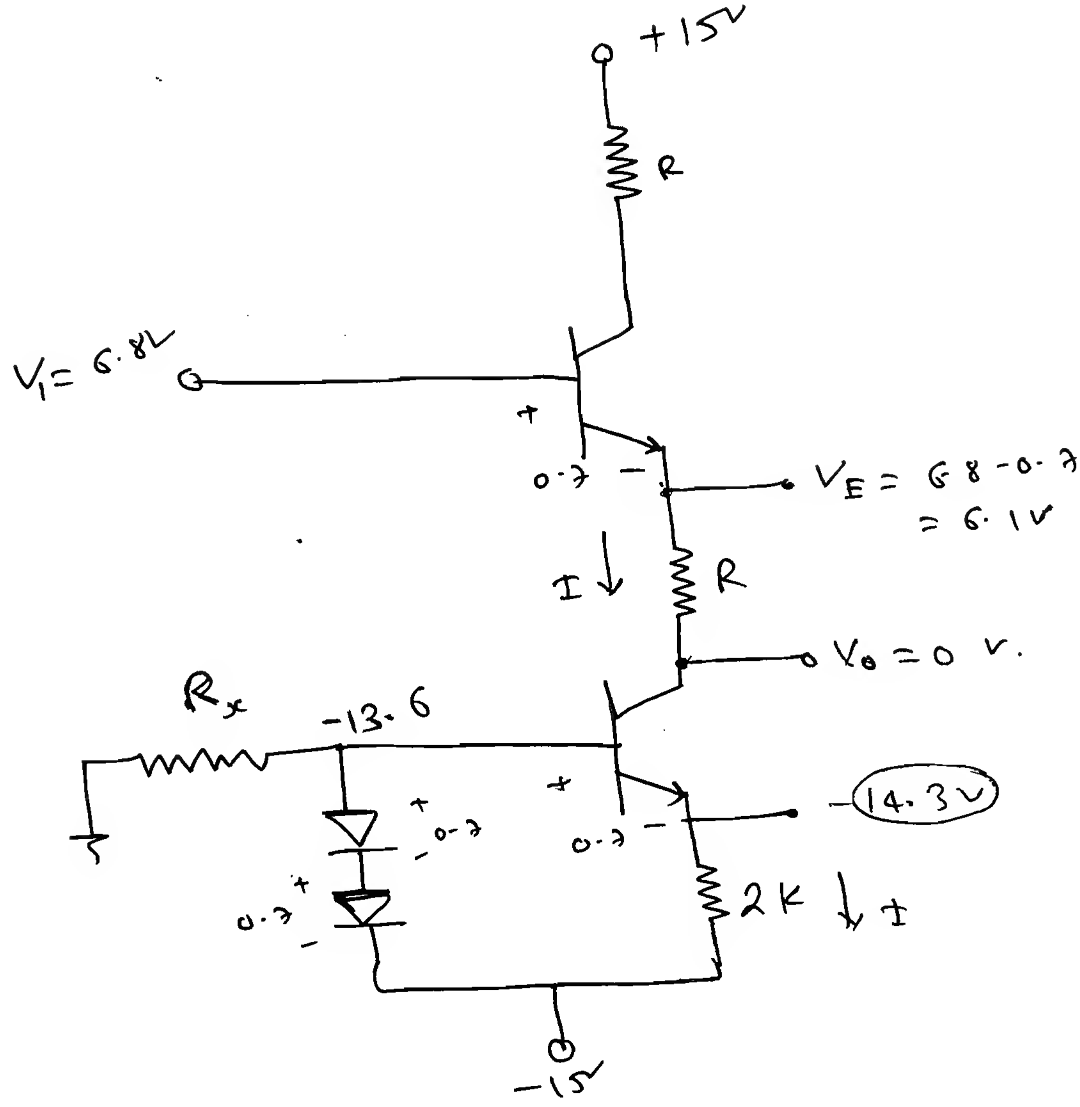
⇓

Dc resistance.

$$R_{AC} = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{6-5}{1.43-1.43} = \frac{1}{h_{oe}} = R_o = \infty.$$

Ac Resistance $\boxed{R_{AC} = \infty.}$

Ex: Find the value of R for DC level shift of 6.8V.



$$I = \frac{-14.3 + 15}{2K}$$

$$I = \frac{6.1 - 0}{R}$$

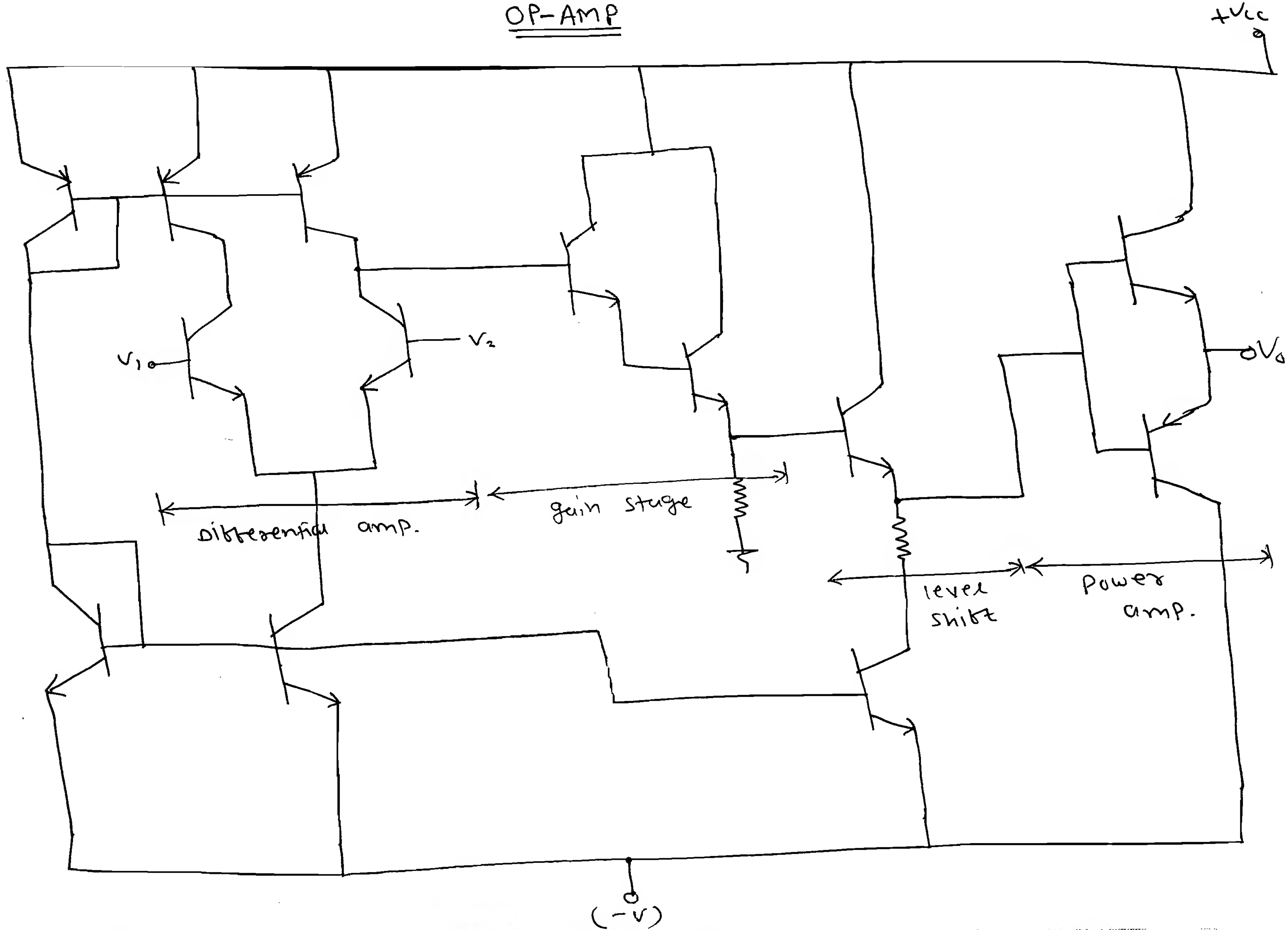
$$\boxed{I = \frac{0.7}{2K}}$$

$$\therefore \frac{6.1}{R} = \frac{0.7}{2K}$$

$\therefore$ ~~I~~

$$\therefore \boxed{R = 17.43mA}$$

OP-AMP



+Vcc
V_1
V_2
V_0
differential amp.
gain stage
level shift
power amp.
(-V)

* Frequency Response:

⇒

Freq. Response

- Magnitude Response
  - LPF
  - HPF
  - BPF
  - BSF
- Phase Response
  - All pass filter (or) Delay filter.

(V_o / V_{in})

⇒

1. LPF ⇒ $\dfrac{K}{1+s\tau}$

2. HPF ⇒ $\dfrac{Ks}{1+s\tau}$.

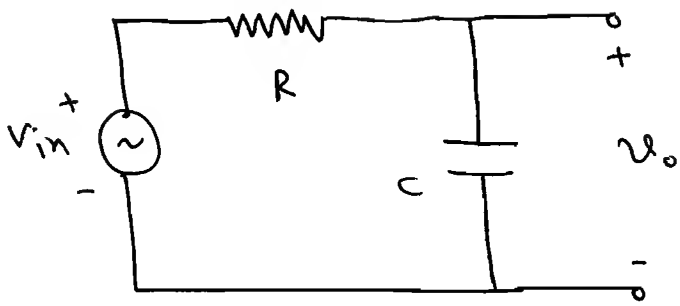
3. BPF ⇒ $\dfrac{Ks}{s^2+2\xi\omega_o s+\omega_o^2}$.

4. BSF ⇒ $\dfrac{K[s^2+\omega_o^2]}{s^2+2\xi\omega_o s+\omega_o^2}$.

5. All pass filter ⇒ $\dfrac{s-a}{s+a}$.

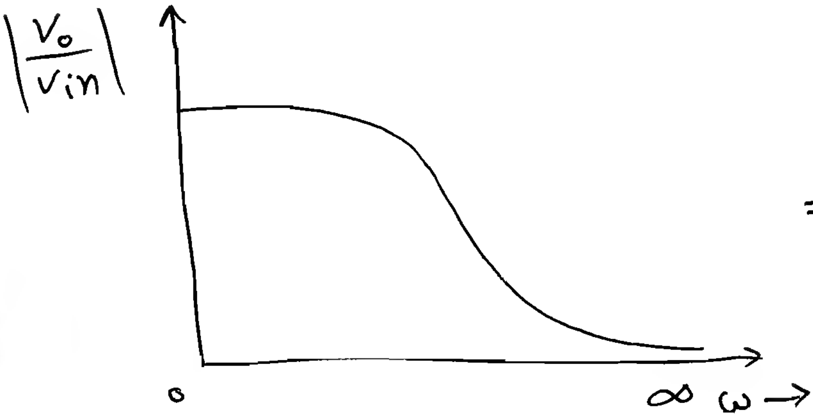
* Recognize the type of filter :

☆



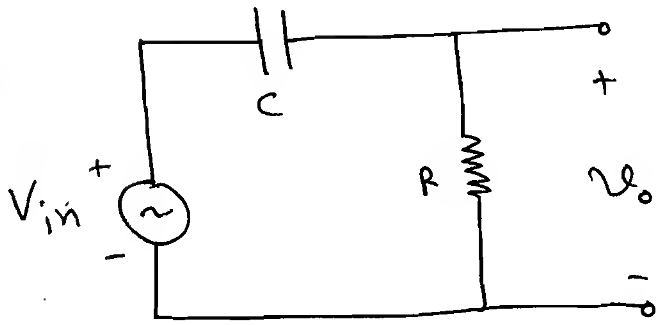
⇒

	$\omega = 0$	$\omega = \infty$
Cap ($1/\omega C$)	(O.S.)	(S.C)
Inductor $\lvert \omega L \rvert$	(S.C)	(O.C)



⇒ Low Pass filter.

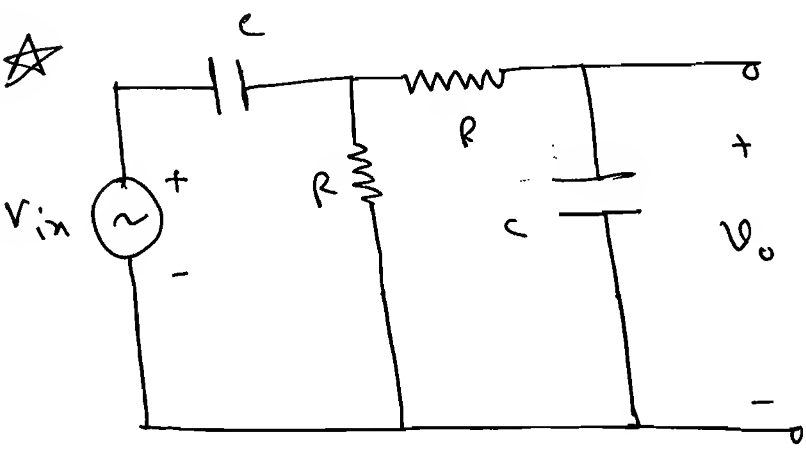
☆

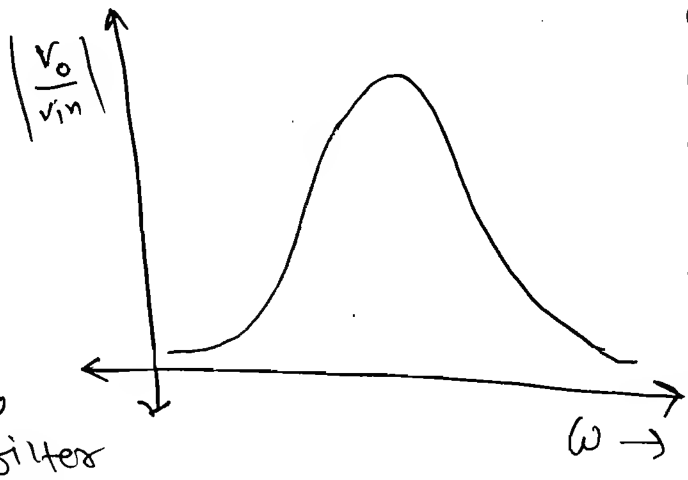


⇒

High pass filter

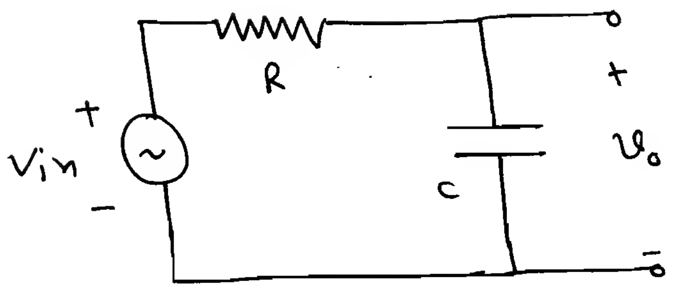
☆

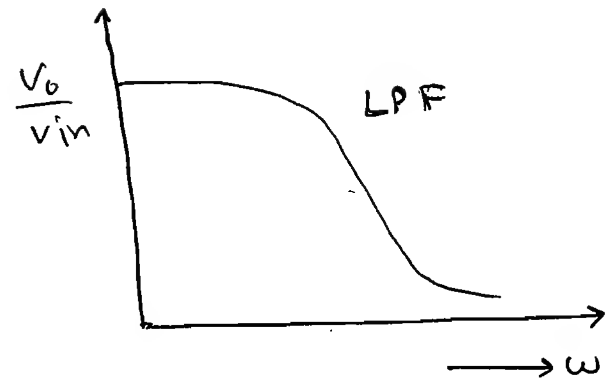




Band Pass filter

$\Rightarrow$ Here we are interested in freq parameter.





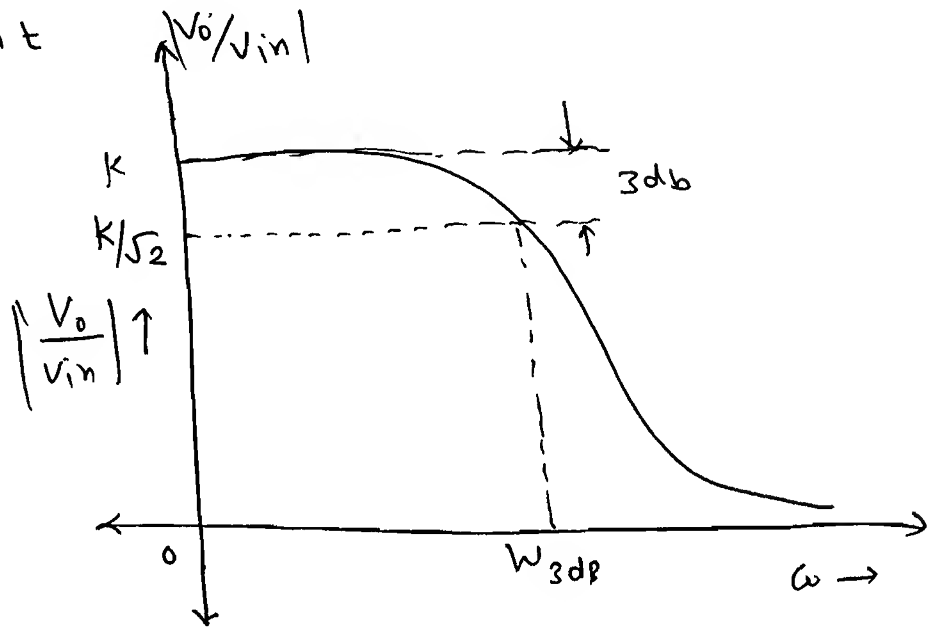
$V_{in} = V_m \sin \omega_1 t$

$= V_m \sin \omega_2 t$

$\vdots$

$V_m \sin \omega_n t$

$\Rightarrow$



$\Rightarrow$ LPF: $\left|\frac{V_o}{V_{in}}\right| = \frac{K}{1+s\tau} = \left|\frac{K}{1+j\omega\tau}\right|$

$$= \frac{K}{\sqrt{1+\omega^2\tau^2}}$$

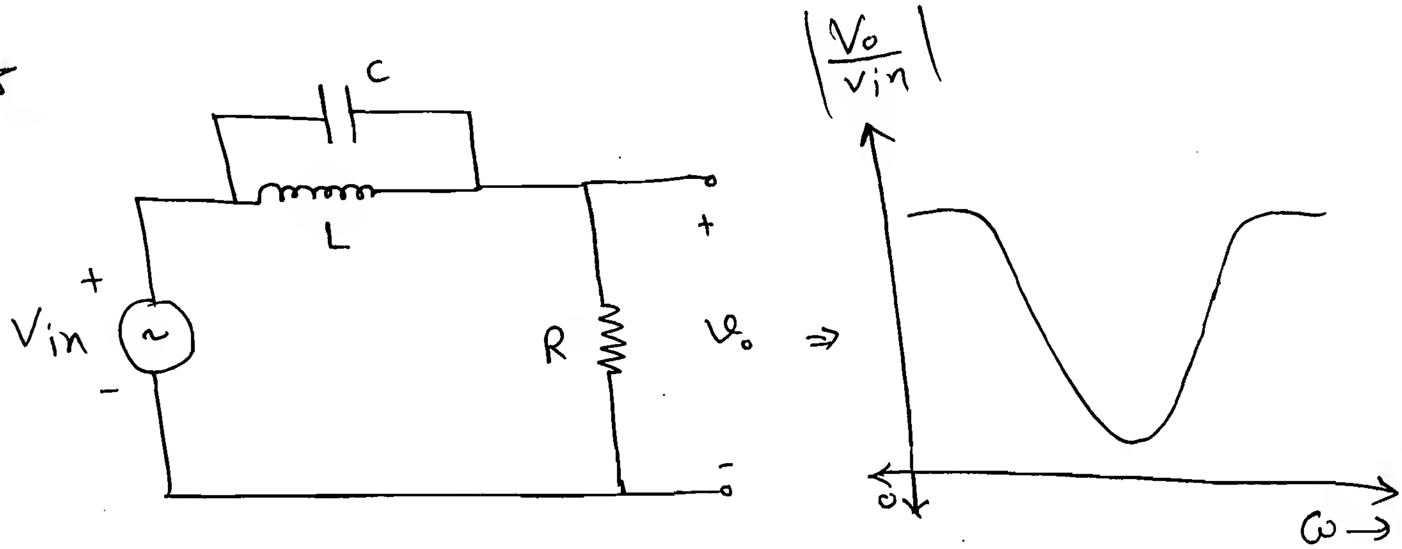
Let $\omega = \omega_{3dB}$ gain reduced to $K/\sqrt{2}$.

$$\therefore \frac{K}{\sqrt{2}} = \frac{K}{\sqrt{1+(\omega_{3dB}\tau)^2}}$$

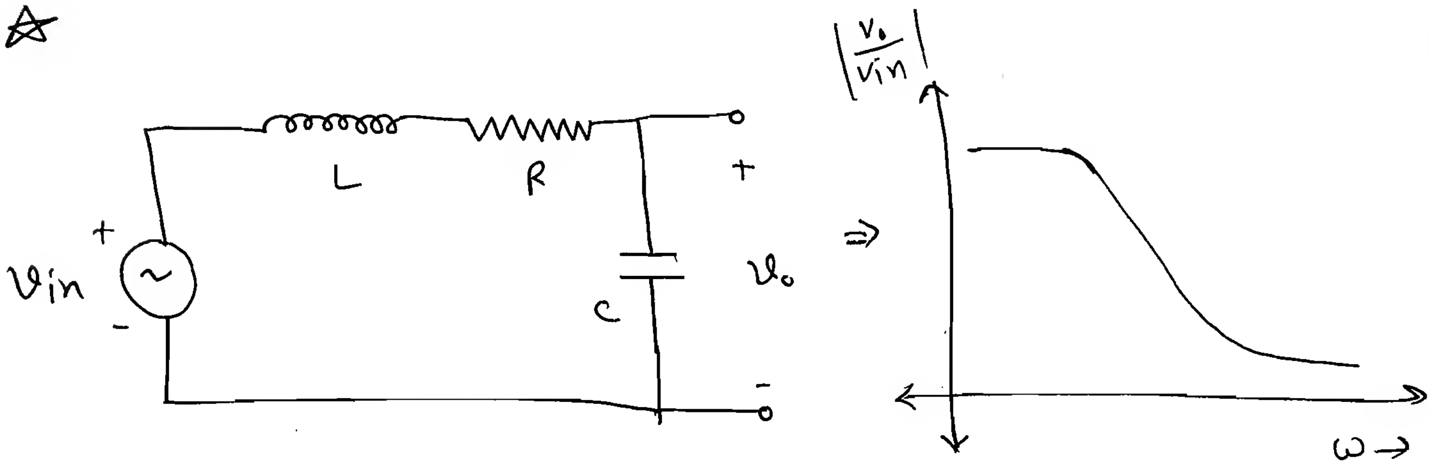
$$\therefore 1 + \omega_{3dB}^2 \cdot \tau^2 = 2.$$

$$\therefore \omega_{3db}^2 = \frac{1}{\tau^2}.$$

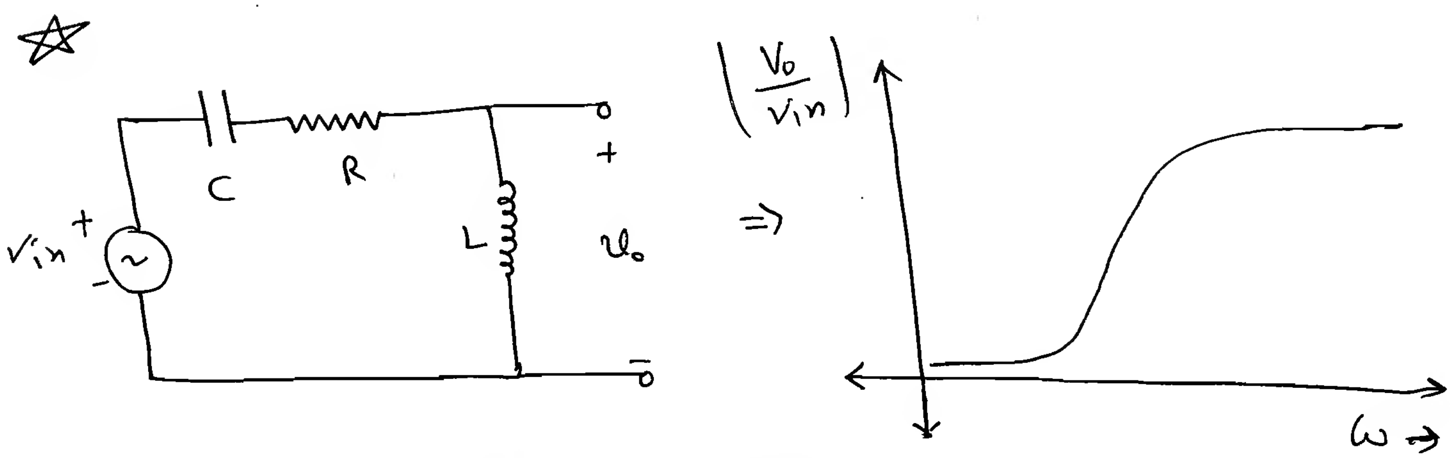
$$\therefore \boxed{\omega_{3db} = \frac{1}{\tau}}.$$



Band stop filter.

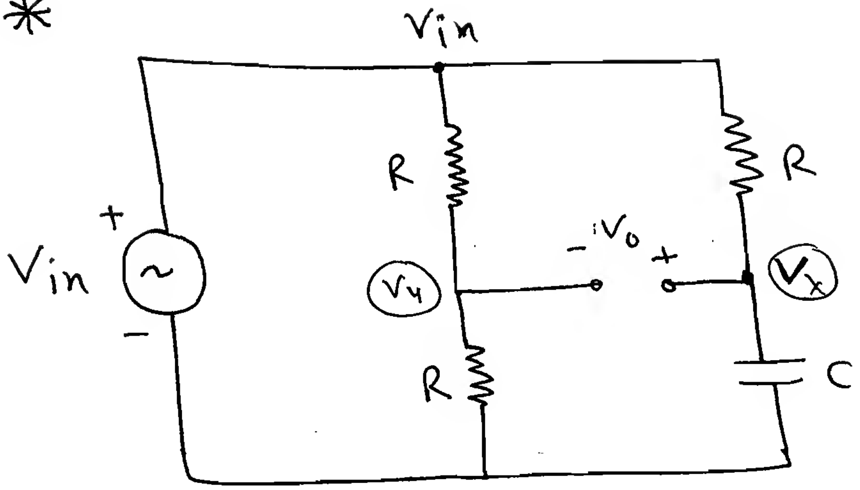


Low Pass filter.



High pass filter

*



$\Rightarrow \quad V_o = V_x - V_y.$

$$V_x = \left(\frac{\frac{1}{sC}}{R + \frac{1}{sC}} \right) V_{in} = \frac{V_{in}}{1 + sCR}$$

$$V_y = \left(\frac{R}{R+R} \right) V_{in} = \frac{V_{in}}{2}.$$

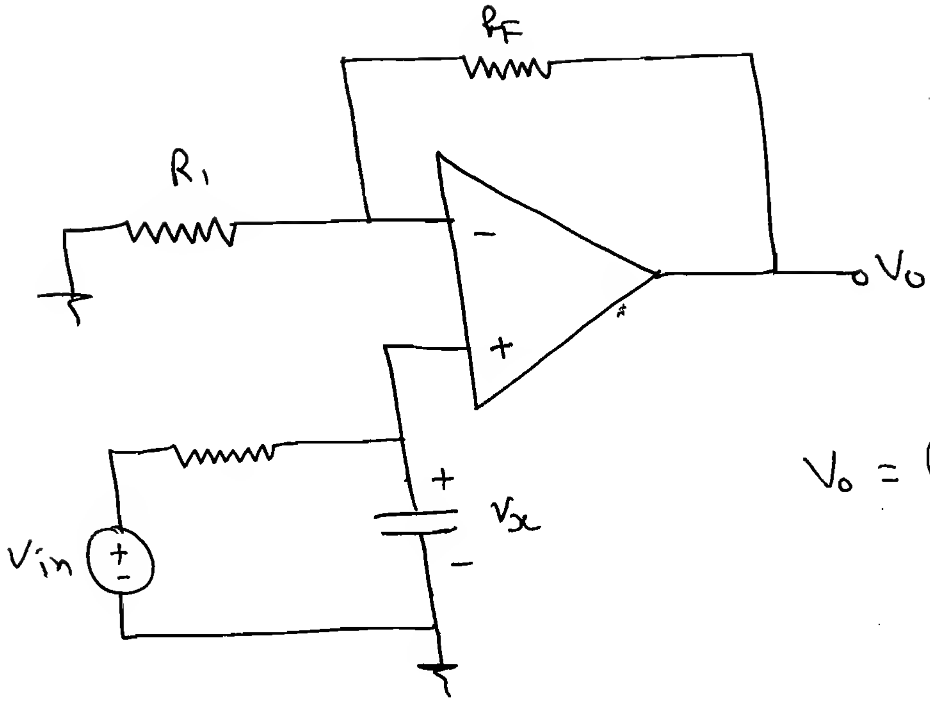
$$\therefore V_o = V_{in} \left[\frac{1}{1+sCR} - \frac{1}{2} \right].$$

$$V_o = V_{in} \left[\frac{2 - 1 - sCR}{2(1+sCR)} \right]$$

$$\therefore \frac{V_o}{V_{in}} = \frac{1 - sCR}{2 + 2sCR} = \frac{s-a}{s+a} \text{ form.}$$

$\therefore$ **All pass filter.**

*



$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_x.$$

=> Use the Passive Components at high freq. (R, L, C's).

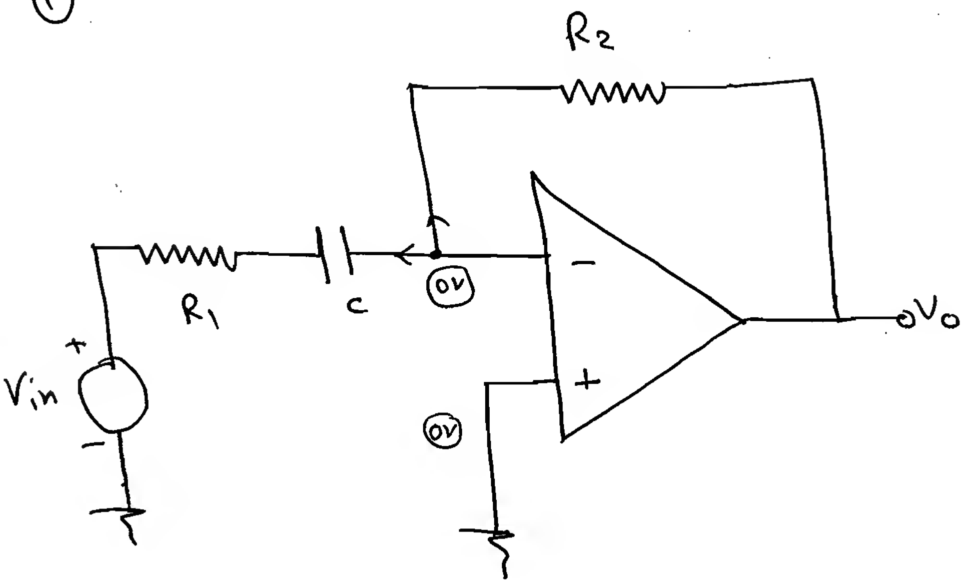
=> Opamp can not work at high freq.

Opamp itself is a lowpass filter.

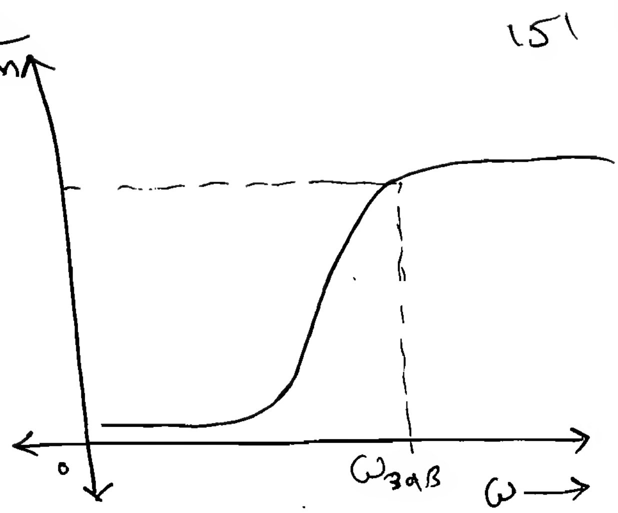
Because of Restrected by Gain BW Product.

☆ Recognize the type of the filter also find the transfer f^n V_o/V_{in}.

①



$\Rightarrow$ By NDA,



$$\frac{0 - V_o}{R_2} + \frac{0 - V_{in}}{R_1 + \frac{1}{sC}} = 0.$$

$$\therefore \frac{V_o}{R_2} = \frac{-V_{in} \times sC}{1 + R_1 sC}.$$

$$\therefore \frac{V_o}{V_{in}} = -\frac{R_2 sC}{1 + R_1 sC}.$$

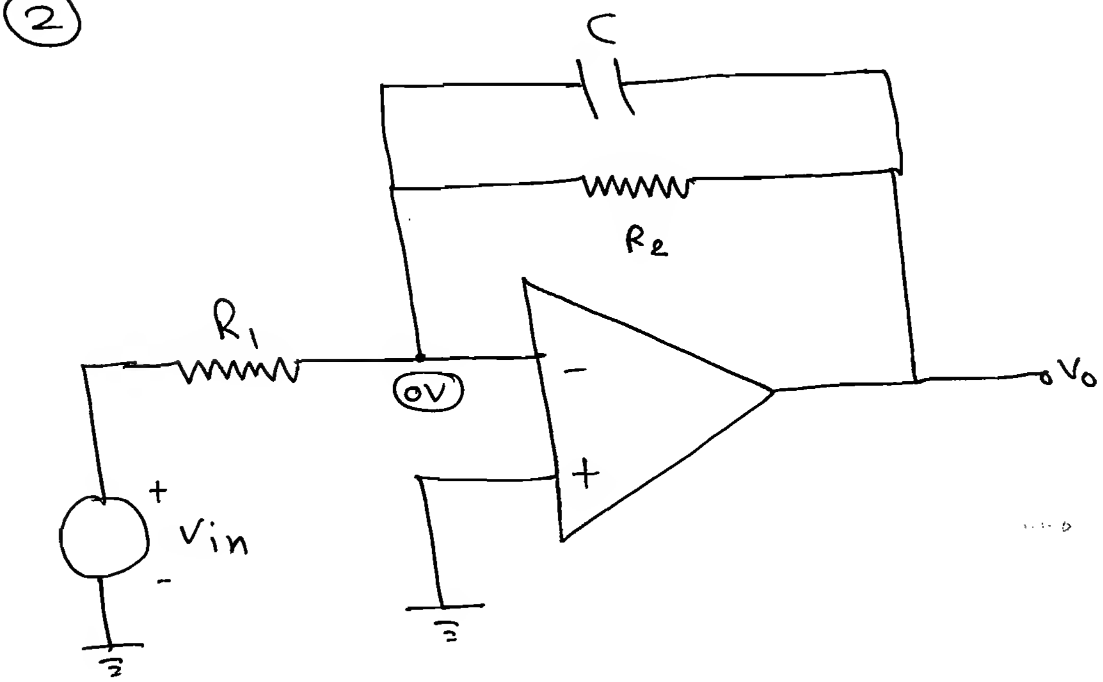
$$\therefore \left|\frac{V_o}{V_{in}}\right| = \left|\frac{R_2 sC}{1 + sCR_1}\right| = \frac{KS}{1 + S\tau}$$

$$\Downarrow$$

$$\boxed{\omega_{3dB} = \frac{1}{\tau} = \frac{1}{RC}}$$

so, High pass filter.

(2)



$$\Rightarrow \frac{0 - V_{in}}{R_1} + \frac{0 - V_o}{C \parallel R_2} = 0.$$

$$\therefore \frac{-V_o}{\frac{R_2 C}{R_2 + C}} = \frac{V_{in}}{R_1}$$

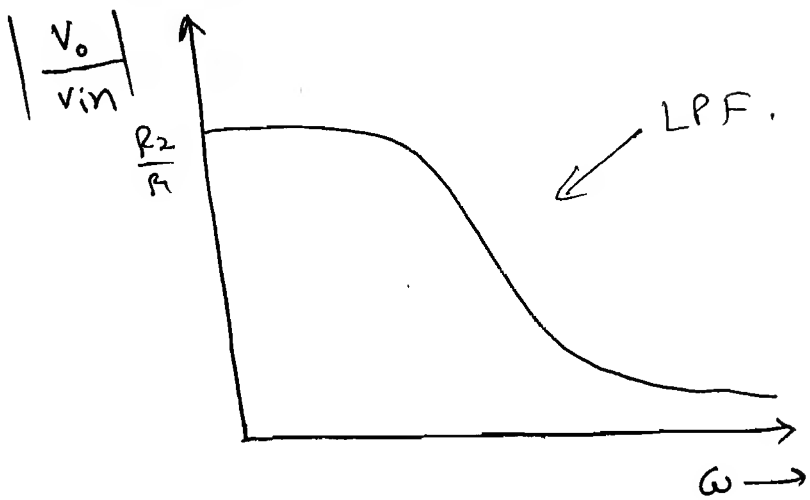
$$\therefore \frac{V_o}{V_{in}} = \frac{R_2 C}{R_1 (\cancel{R} + R_2)}$$

$$= \frac{R_2 / sC}{R_1 \left(R_2 + \frac{1}{sC} \right)}$$

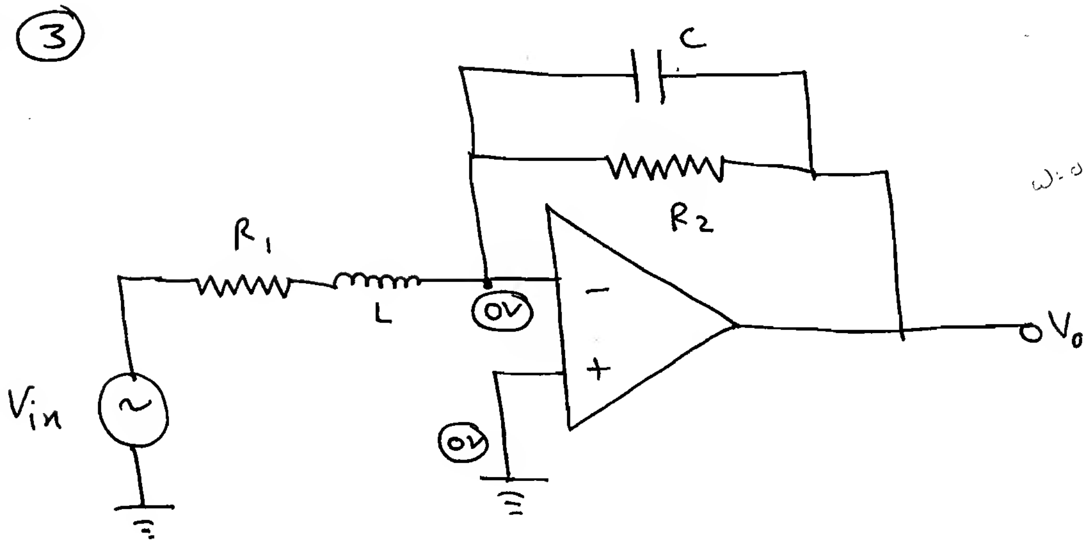
$$\therefore \boxed{\frac{V_o}{V_{in}} = \frac{R_2}{R_1 (1 + sCR_2)}} = \frac{K}{1 + s\tau}$$

So, Low pass filter.

$$\boxed{\omega_{3dB} = \frac{1}{\tau} = \frac{1}{R_2 C}}$$



③



By NDA,
$$\frac{0 - V_{in}}{R + sL} + \frac{0 - V_o}{R_2 \parallel \frac{1}{sC}} = 0$$

$$\therefore \frac{V_{in}}{R_1 + SL} = -V_o \left[\frac{R_2 + \frac{1}{SC}}{R_2 / SC} \right].$$

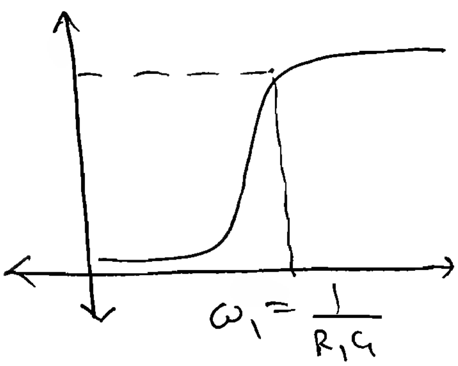
$$\therefore \frac{V_{in}}{R_1 + SL} = -V_o \left[\frac{1 + R_2 SC}{R_2} \right].$$

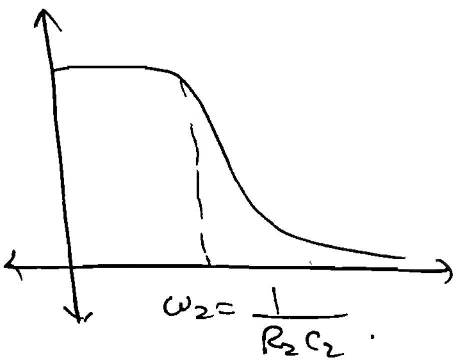
$$\therefore \frac{V_o}{V_{in}} = -\frac{R_2}{(R_1 + SL)(1 + R_2 SC)}.$$

$$\therefore \frac{V_o}{V_{in}} = -\frac{R_2}{R_1 + R_1 R_2 SC + SL + R_2 LCS^2}$$

$$\frac{V_o}{V_{in}} = \frac{-\frac{1}{LC}}{S^2 + \left(\frac{R_1 R_2 C + L}{R_2 LC}\right) S + \frac{R_1}{R_2 LC}}$$

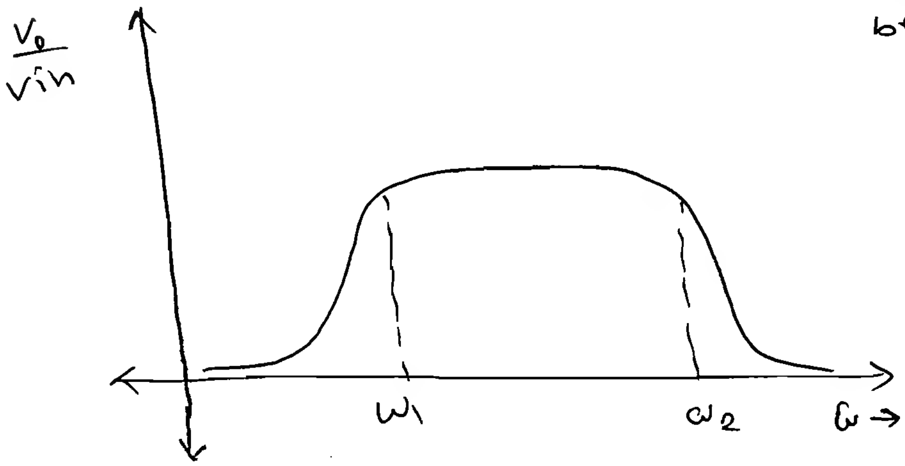
$$\frac{V_o}{V_{in}} = \frac{-R_2 / R_1}{(1 + SCR_2)\left(1 + \frac{SL}{R_1}\right)}.$$





$\Rightarrow$ For Band pass filter ; $\omega_2 > \omega_1$

$\Rightarrow$ otherwise it will be Band Stop filter



$$Z_2 = \frac{R_2}{1 + R_2 C S} \quad , \quad Z_1 = R_1 + SL.$$

$$\left| \frac{V_o}{v_{in}} \right| = \left| \frac{Z_2}{Z_1} \right|$$

$$= \frac{R_2 / R_1}{(1 + SCR_2)\left(1 + \frac{SL}{R_1}\right)}$$

$$= \frac{K}{(1 + ST_1)(1 + ST_2)}$$

$\tau_1 = R_2 C$

$\tau_2 = L / R_1$.

$\Rightarrow$ 2^{nd} order LPF

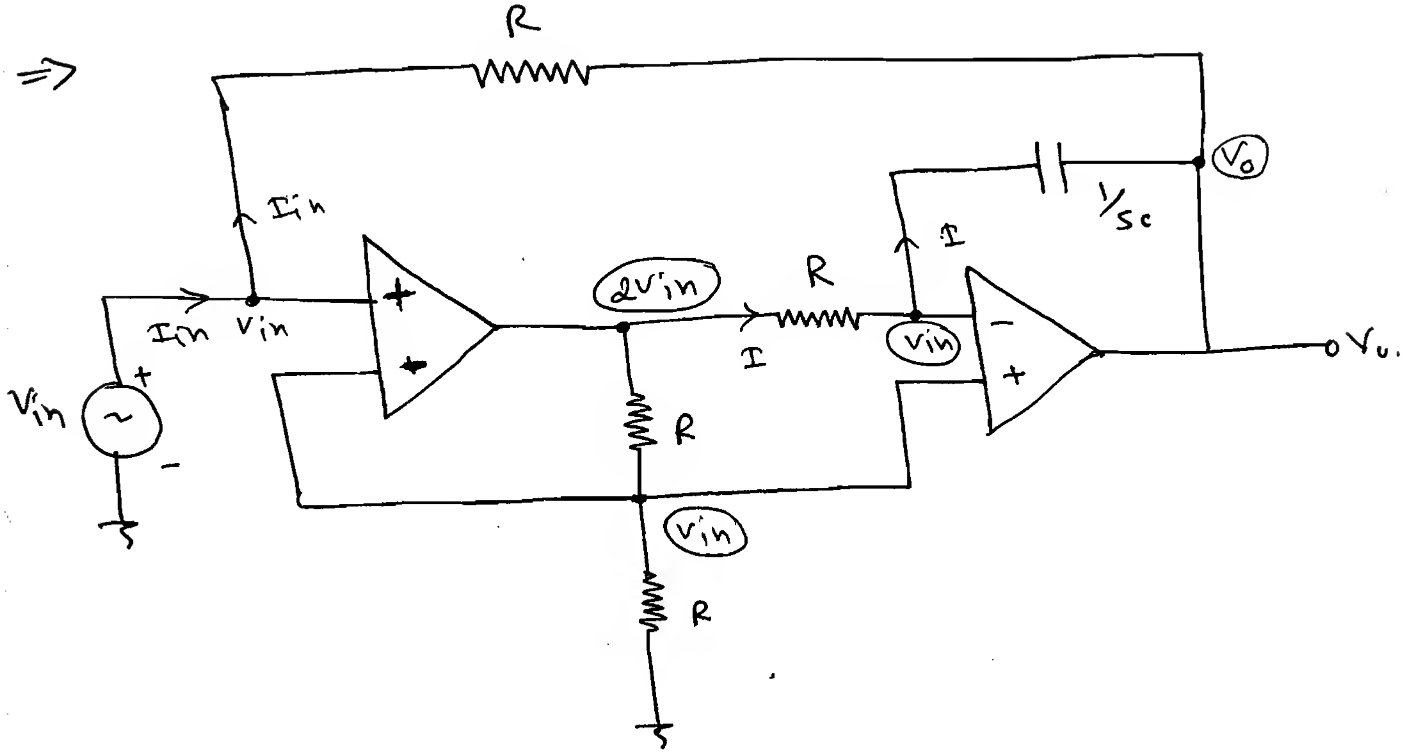
* Simulation of Inductor [Gyrator]

$\Rightarrow \quad \tau = RC = \frac{L}{R}.$

$\Rightarrow \quad L = CR^2.$

$$\frac{V_{in}}{I_{in}} = Z_{in} = sL = sCR^2.$$

$\Rightarrow$



$$\Rightarrow \quad I = \frac{2V_{in} - V_{in}}{R} = \frac{V_{in}}{R}.$$

$$\rightarrow \quad V_{in} - V_o = I\left(\frac{1}{sc}\right).$$

$$\therefore \quad V_{in} - V_o = \frac{V_{in}}{R}.\left(\frac{1}{sc}\right).$$

$$\therefore \quad V_o = V_{in} - V_{in}\left(\frac{1}{sCR}\right).$$

$$\Rightarrow \quad I_{in} = \frac{V_{in} - V_o}{R}$$

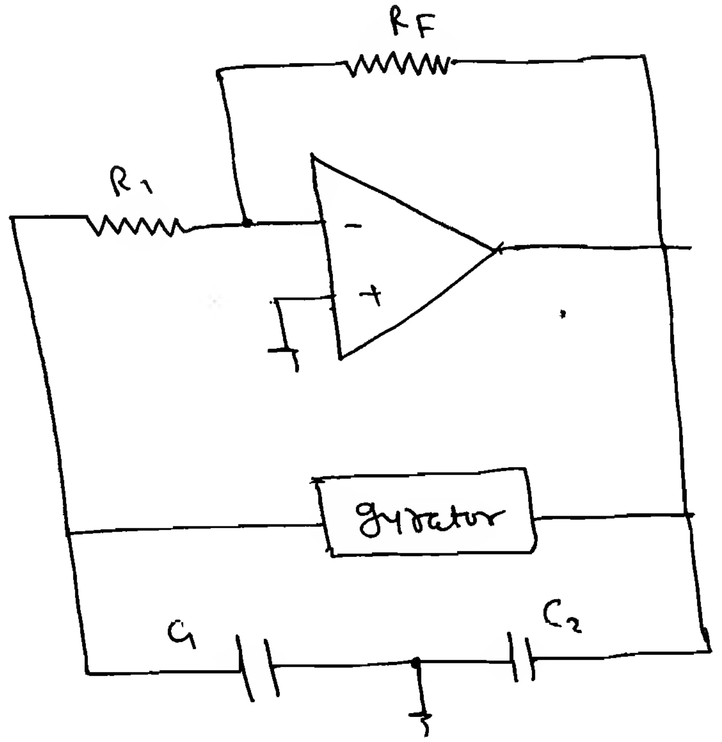
$$I_{in} = \frac{V_{in} - V_{in} + V_{in}\left(\frac{1}{sCR}\right)}{R}$$

$\therefore \quad I_{in} = V_{in}\left(\frac{1}{sCR^2}\right).$

$\therefore \quad \frac{V_{in}}{I_{in}} = Z_{in} = sCR^2. = sL_{eq}.$

$\therefore \quad \boxed{L = CR^2}$

* Colpitt's oscillator:

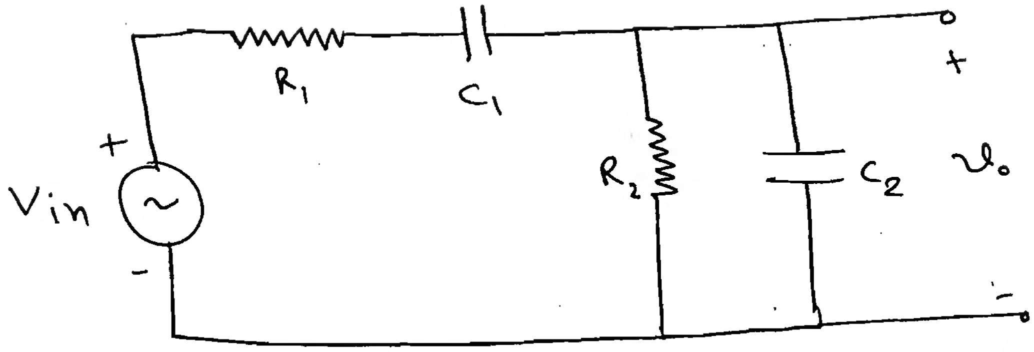


$\Rightarrow \quad f = \frac{1}{2\pi\sqrt{LC}}$

$\therefore \quad f = \frac{1}{2\pi\sqrt{R^2 c^2}}$

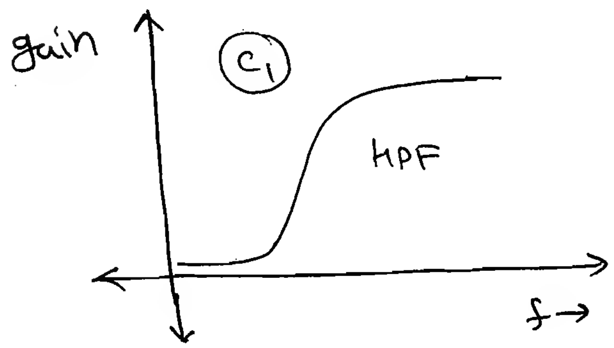
$\boxed{f = \frac{1}{2\pi RC}}$

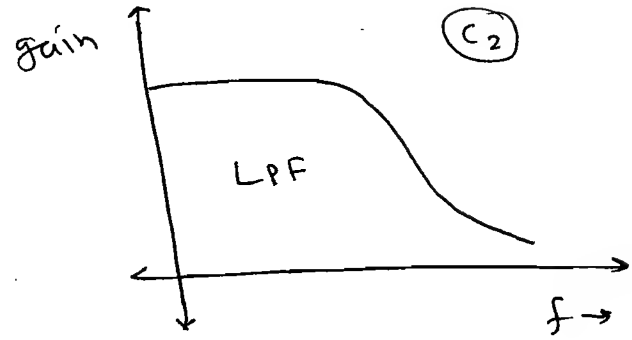
*

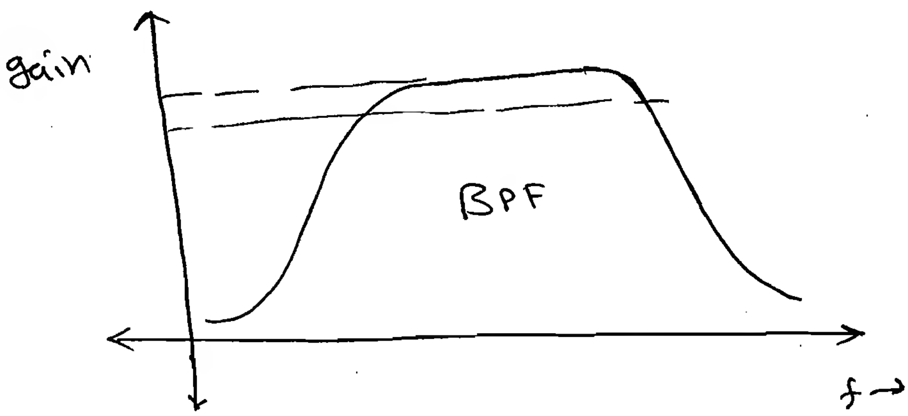


(β N/w of wein bridge oscillator).

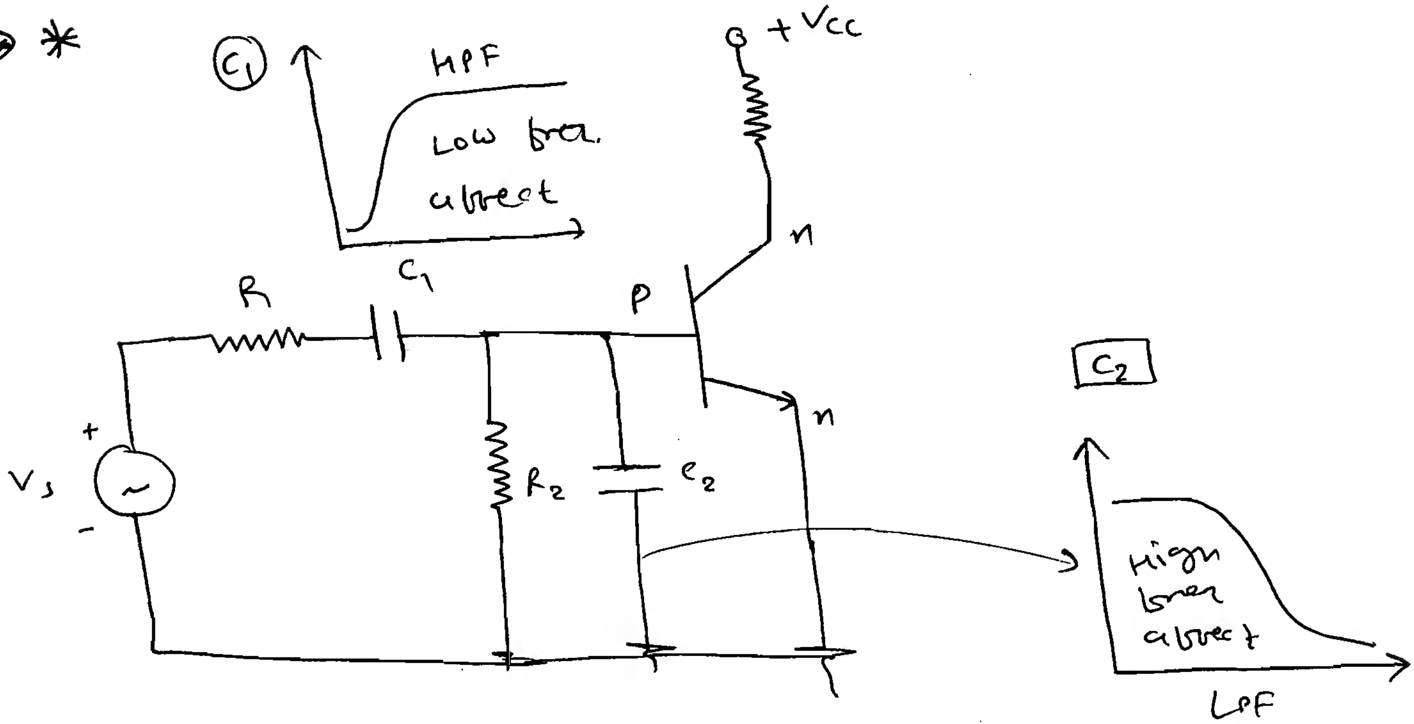
=>





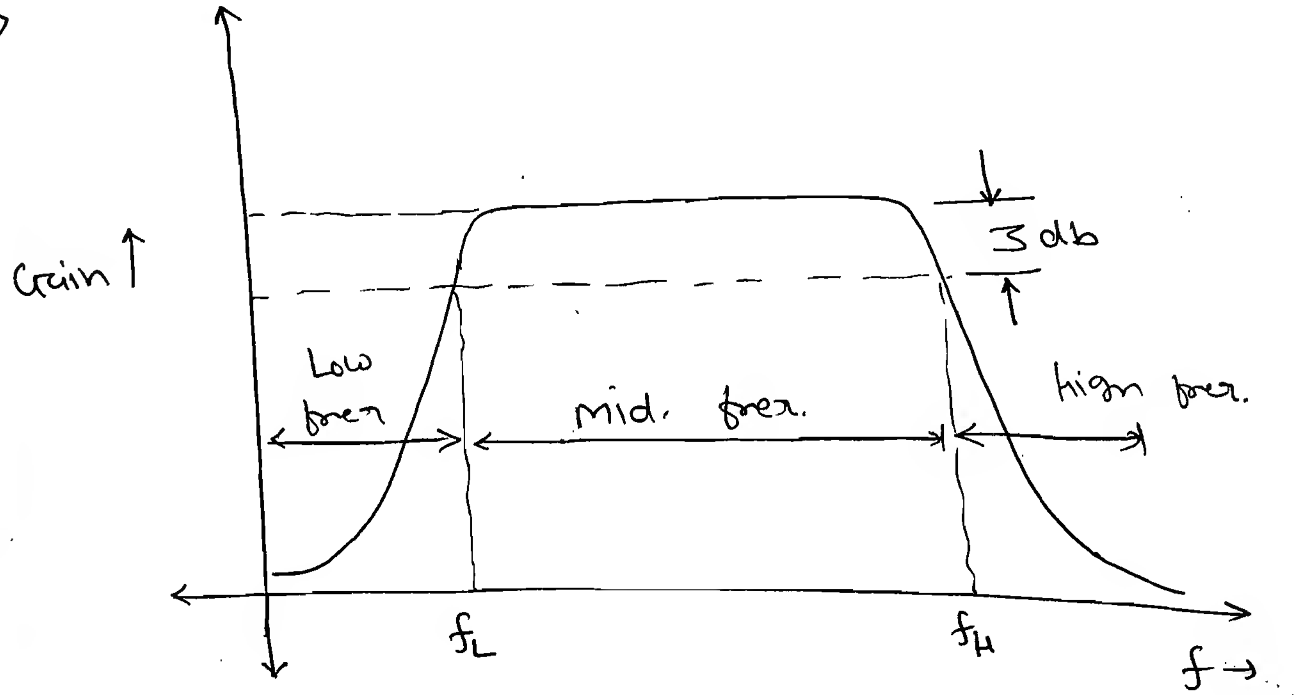


=> *



⇒ Frequency response of a Common emitter amplifier is a BPF. The terms that affect low freq. gain are constant over a high freq. range. Similarly, the terms that affect high freq. gain are constant over low freq. Hence, low and high freq. analysis are two independent problems.

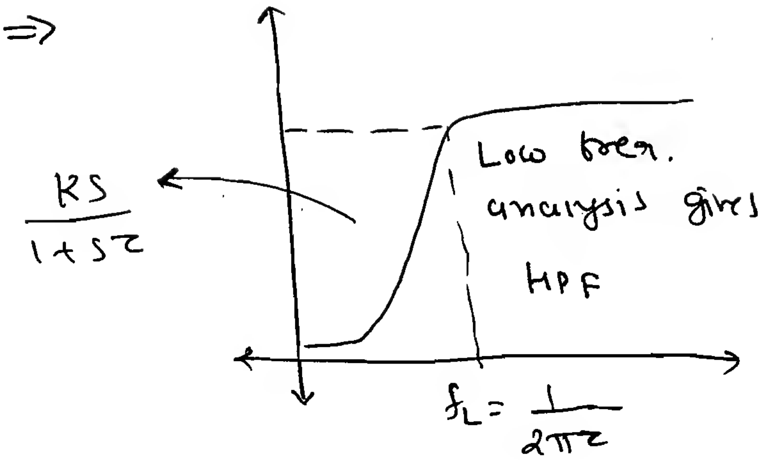
⇒

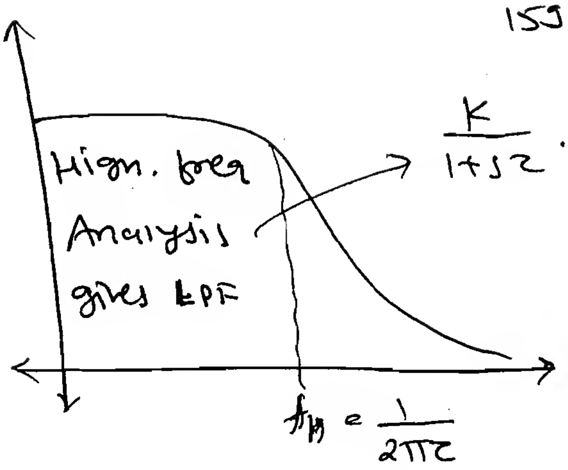


⇒

	Coupling and bypass Cap.	Parasitic and Load Capacitor
1. Low freq.	$\boxed{\text{Consider}}$	Better open
2. mid freq.	Short	open
3. High freq.	Better short	$\boxed{\text{Consider}}$

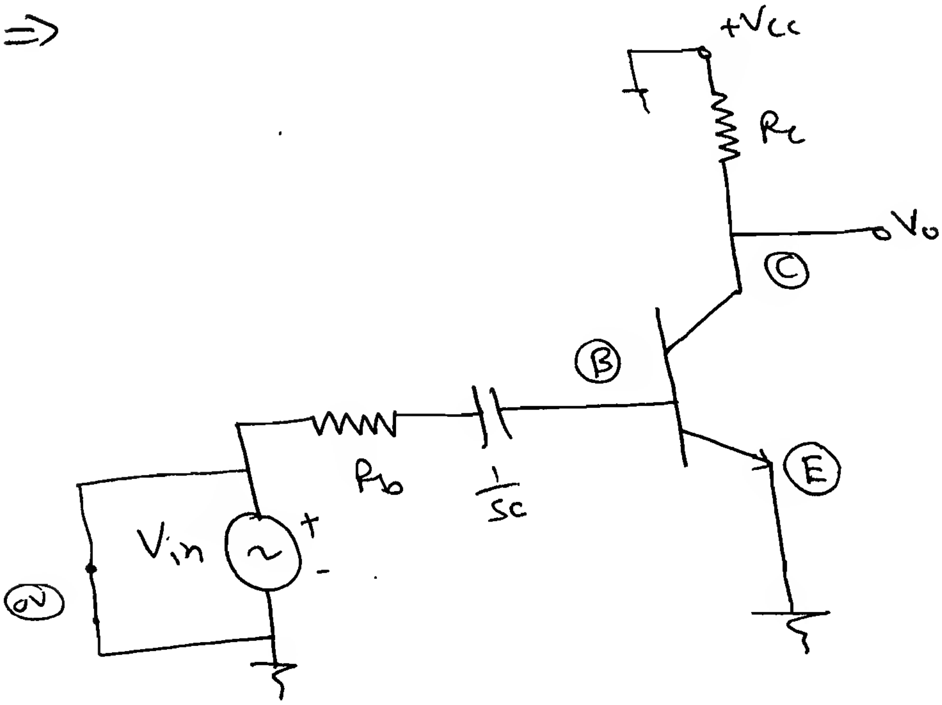
=>





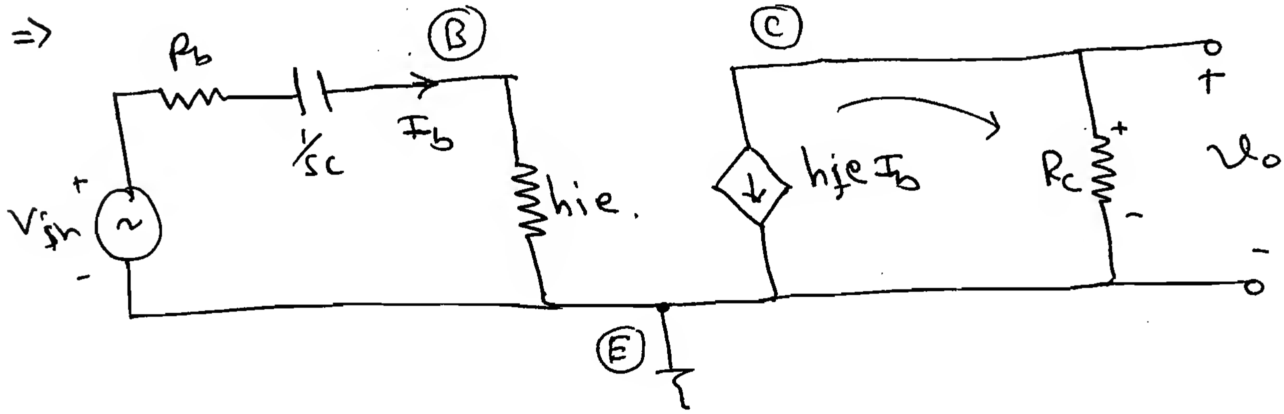
* Effect of Coupling Capacitor on Low freq. Response:

=>



	S=0	S=∞
LPF	Gain	0
HPF	0	Gain

=>

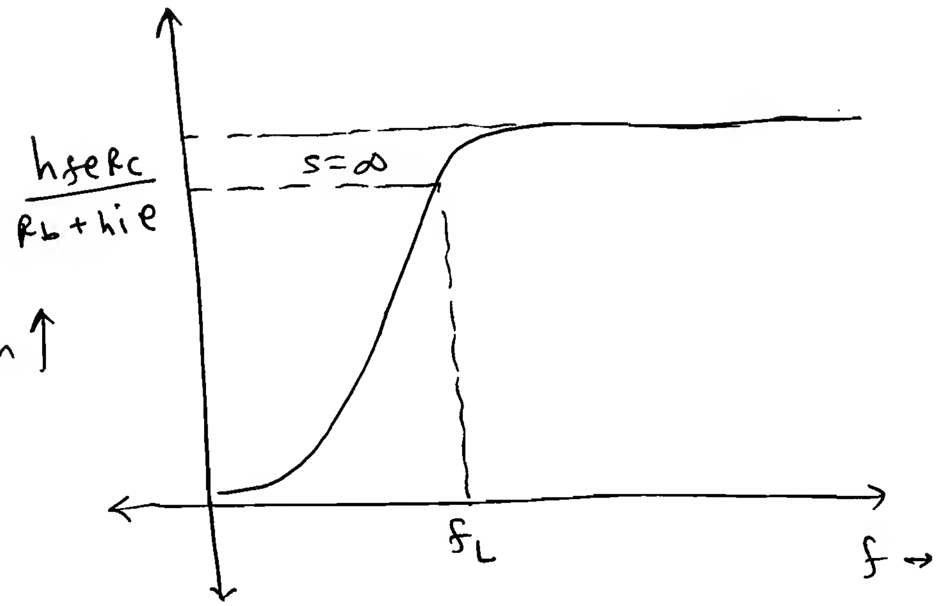


=> $V_o = -h_{fe} \cdot R_c \cdot I_b \quad -(1)$

$$\Rightarrow \quad V_{in} = I_b \left[R_b + h_{ie} + \frac{1}{sC} \right] \quad -②$$

$$\left| \frac{V_o}{V_{in}} \right| = \frac{[h_{fe} \cdot R_c C]\, s}{1 + sC[R_b + h_{ie}]} = \frac{ks}{1 + s\tau} \qquad \boxed{HPF}$$

$\Rightarrow$



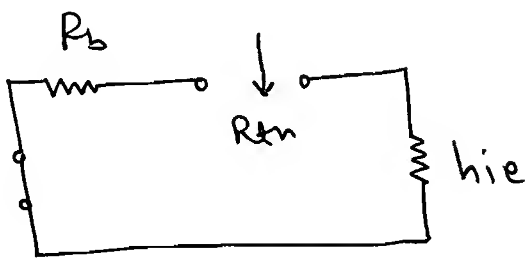
$$\Rightarrow \quad \omega_L = \frac{1}{\tau}$$

$$f_L = \frac{1}{2\pi\tau}.$$

$$\therefore \quad f_L = \frac{1}{2\pi[R_b + h_{ie}]C}.$$

(OR)

$$\Rightarrow \quad \tau = R_{th} \cdot C$$



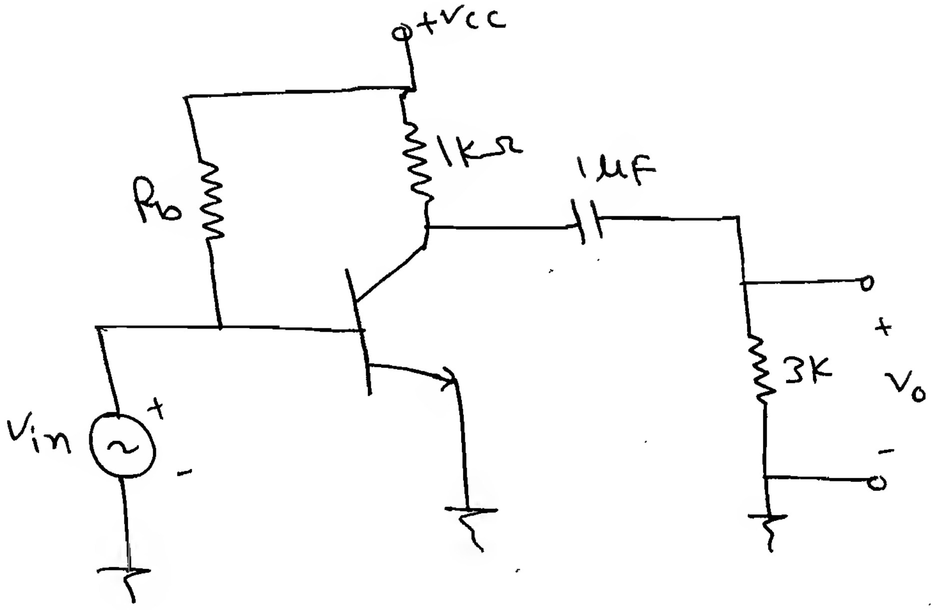
$$\tau = [R_b + h_{ie}]C$$

$$\therefore \quad f_L = \frac{1}{2\pi\tau} = \frac{1}{2\pi[R_b + h_{ie}]C}.$$

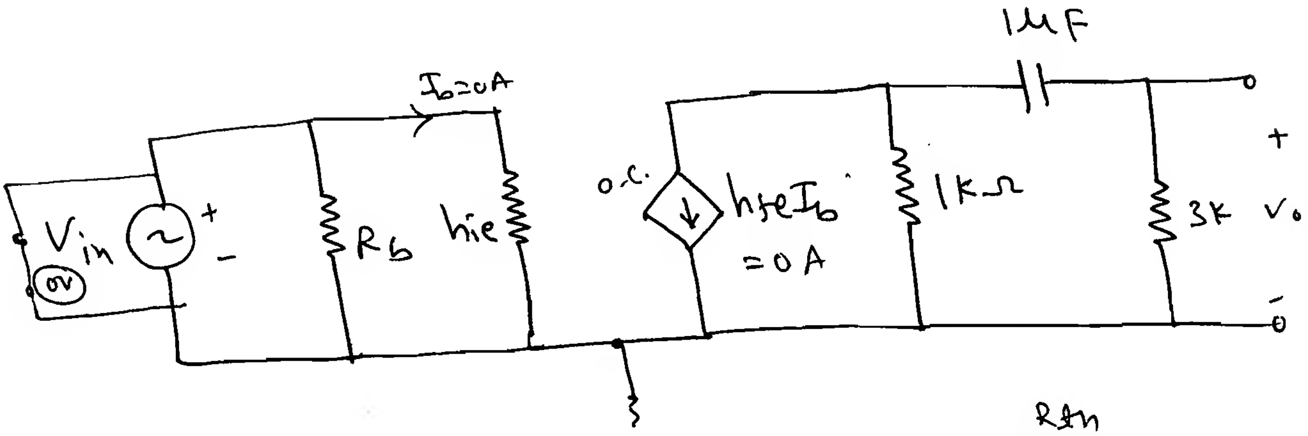
Ex-1 Find the cutoff freq. due to an o/p

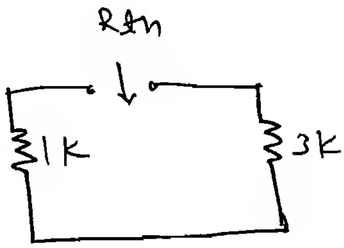
Capacitor given.

⇒



Ans:





$\tau = R_{th} \cdot C$

$\therefore \tau = 4K \cdot 1\mu F$

$\tau = 4 \times 10^{-3}$ sec

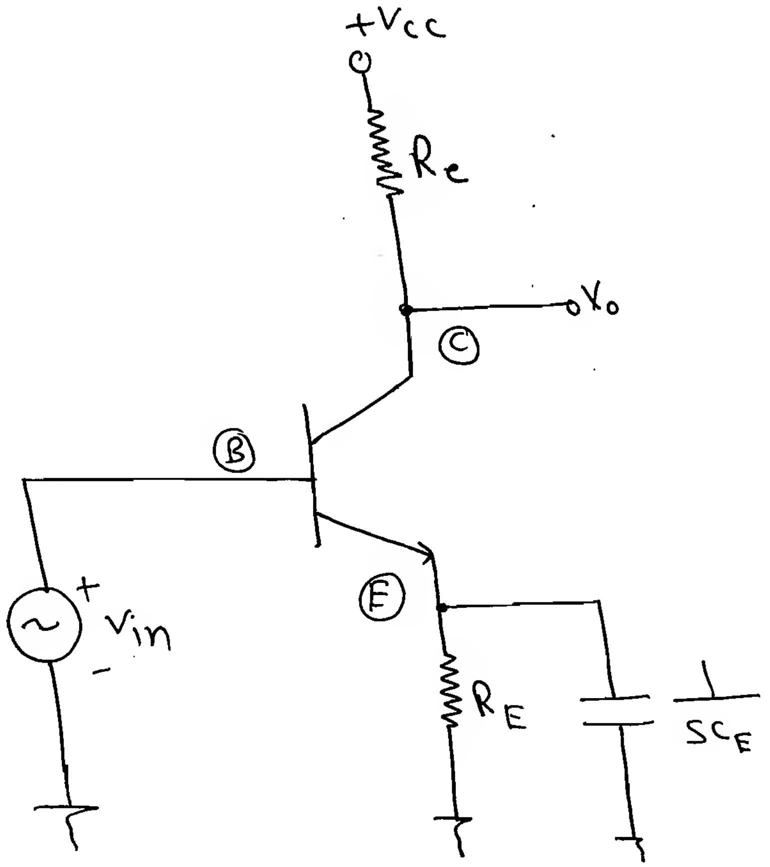
$\therefore$ @3db $f_L = \frac{1}{2\pi\tau}$.

$\therefore f_L = \frac{1}{2\pi \times 4 \times 10^{-3}}$

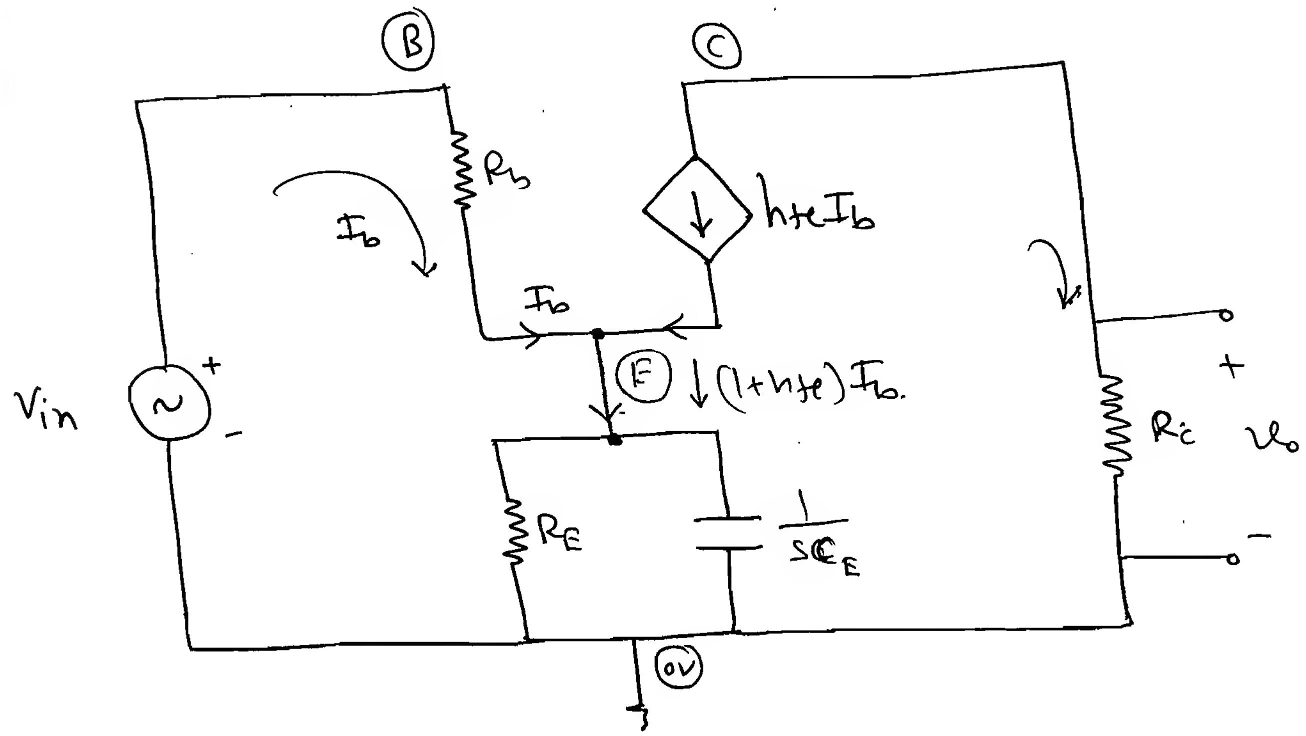
$\therefore \boxed{f_L = \frac{1000}{8\pi} \text{ Hz}}$

* Effect of Bipass Capacitor on Low freq. Response.

⇒



⇒



→ $V_o = -h_{fe} \cdot I_b \cdot R_c$. — ①

$$V_{in} = R_b I_b + (1+h_{fe}) I_b \left[\frac{R_E}{1+R_E \cdot SC_E} \right] \quad — ②$$

$$\therefore \left|\frac{V_o}{V_{in}}\right| = \frac{(h_{fe}.R_c)[1+sC_E.R_E]}{hie + (1+h_{fe})R_E + sC_E R_E hie}.$$

$$\therefore \left|\frac{V_o}{V_{in}}\right| = \frac{h_{fe}.R_c}{hie+(1+h_{fe})R_E} \cdot \left[\frac{1+sC_E.R_E}{1+s\frac{C_E R_E \cdot hie}{hie+(1+h_{fe})R_E}}\right]$$

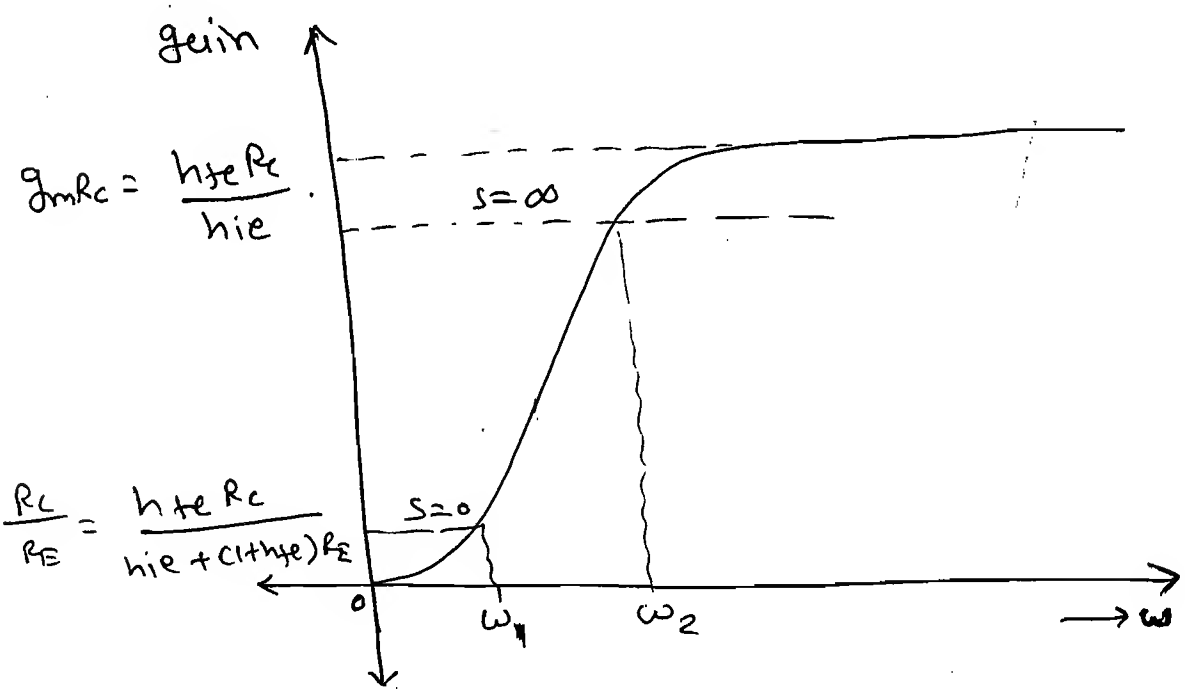
$$\left|\frac{V_o}{V_{in}}\right| = \frac{K[1+s\tau_1]}{1+s\tau_2}.$$

$$\therefore \omega_1 = \frac{1}{\tau_1} = \frac{1}{R_E C_E}.$$

$$\omega_2 = \frac{1}{\tau_2} = \frac{hie + (1+h_{fe})R_E}{C_E R_E \cdot hie}.$$

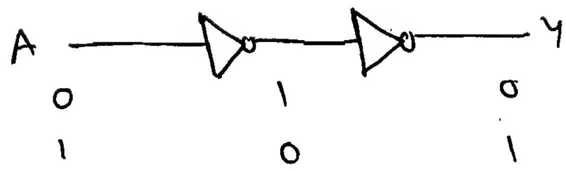
$$\boxed{\omega_2 > \omega_1.}$$

$\Rightarrow$

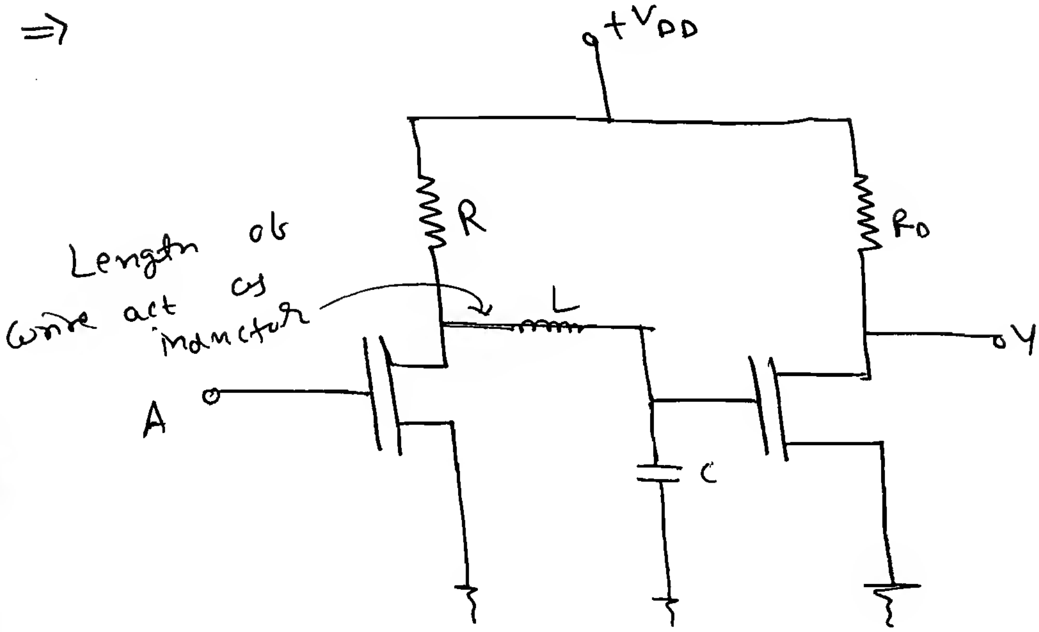


$$\Rightarrow B_W = f_H - f_L$$
$$= 1M - 40Hz$$
$$= 1M.$$
$$B_W = f_H.$$

* High freq. Analysis:



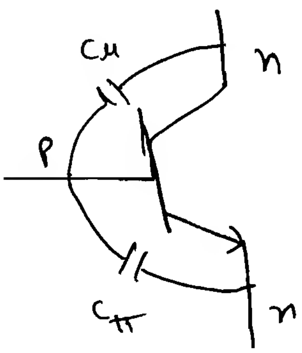
=>



$V_c = \frac{1}{C}\int I dt$

$S.R. = \frac{dV_c}{dt}$

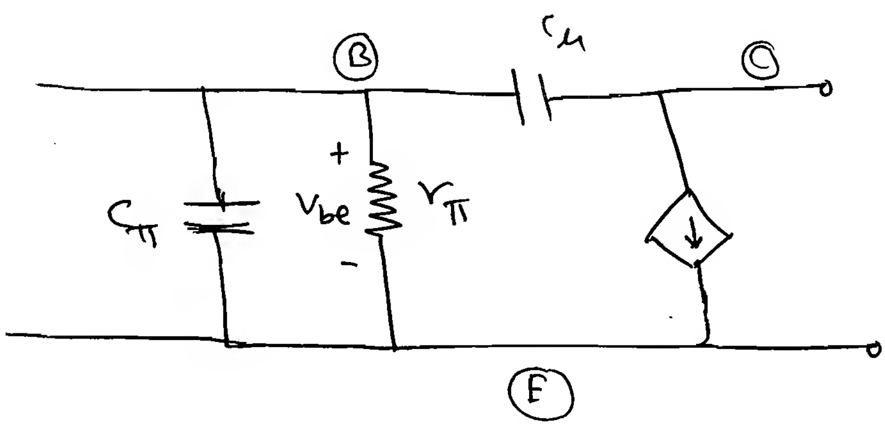
$= I/C$



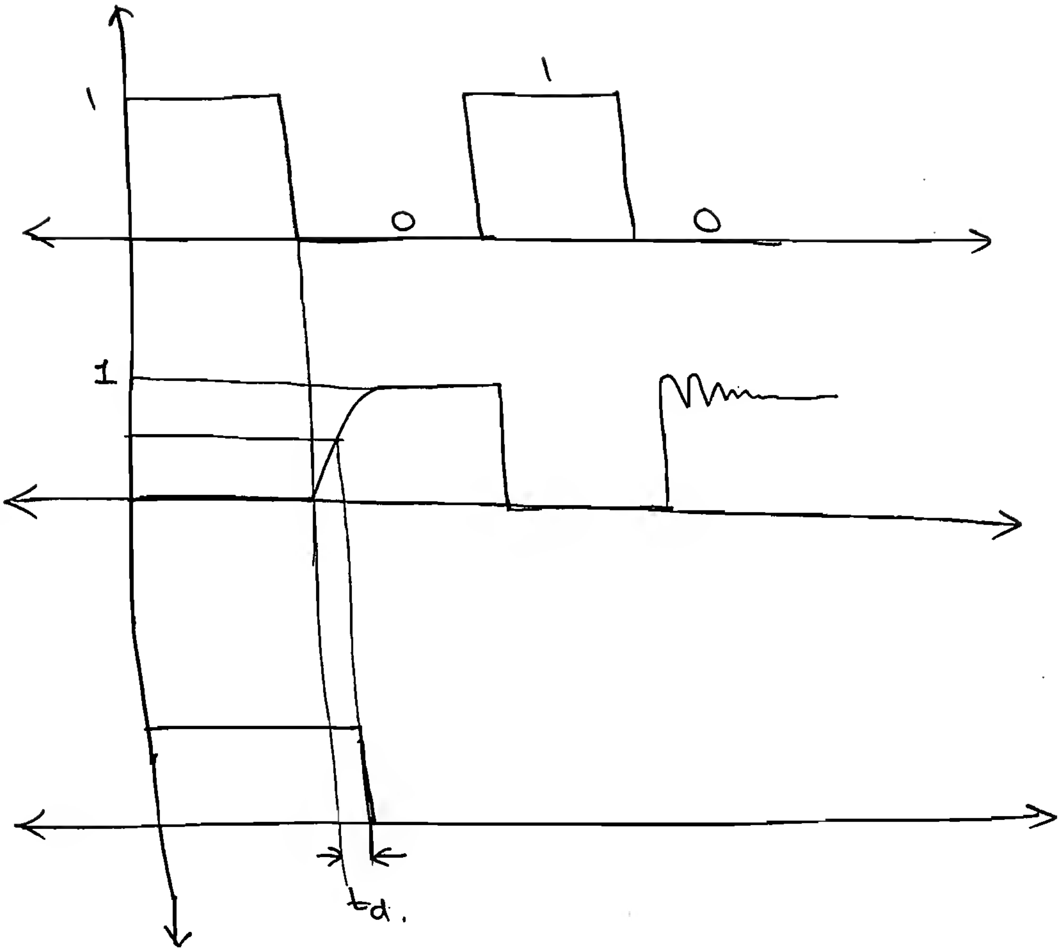
$C_\pi \rightarrow$ forward biased diffusion Cap. (3 pF)

$C_\mu \Rightarrow$ Reverse biased Cap. (0.01 pF)

=>

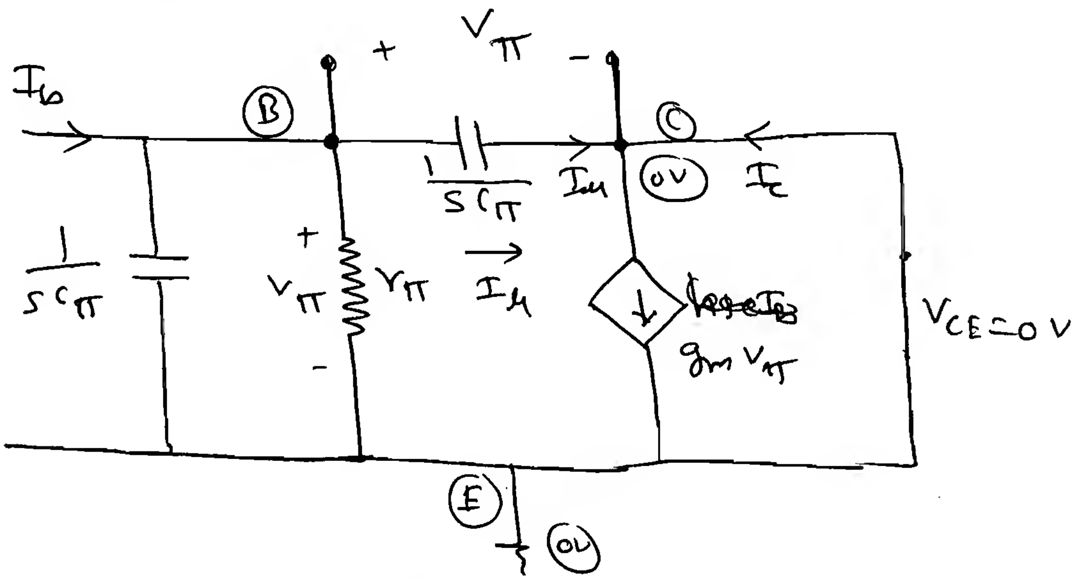


Simplified high freq. model.



*** Calculation of Unity gain freq. & 3db Bandwidth from Short circuit current gain β (OR) h_{fe}.**

⇒



⇒ $I_c = h_{fe} I_b + h_{oe} V_{ce}$.

$\beta = h_{fe} = \left.\dfrac{I_c}{I_b}\right|_{V_{CE}=0}$ (SC forward current gain)

By KCL, $I_\mu + I_c = g_m V_\pi$

$\therefore \; V_\pi [sC_\mu] + I_c = g_m V_\pi$

$\therefore \; I_c = [g_m - \underbrace{sC_\mu}_{\text{neglect}}] V_\pi$

$\Rightarrow \; I_c = g_m V_\pi \quad -(1)$

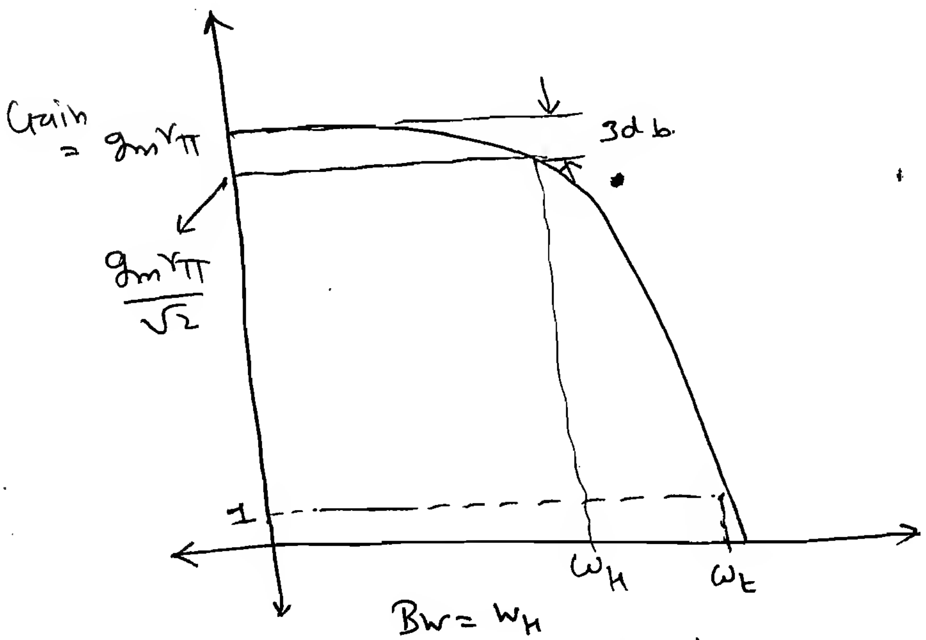
$\rightarrow \; I_b = V_\pi [sC_\pi] + \frac{V_\pi}{r_\pi} + V_\pi [sC_\mu].$

$I_b = V_\pi \left[\frac{1}{r_\pi} + c[C_\pi + C_\mu] \right]$

$$\therefore \left| \frac{I_c}{I_b} \right| = \frac{g_m \cdot r_\pi}{1 + s r_\pi [C_\pi + C_\mu]} = \frac{K}{1 + s\tau}$$

$$= \frac{\beta_0}{1 + s r_\pi [C_\pi + C_\mu]}$$

$\Rightarrow$



$BW = \omega_H$

$= \omega_{3db} = \frac{1}{\tau}$

$\omega_t = \text{gain} \cdot BW$

* Gain (K) $= g_m r_\pi$

* 3db BW $= \dfrac{1}{2\pi\tau}$

$$= \frac{1}{2\pi r_\pi [C_\pi + C_\mu]}$$

* Gain. BW $= \dfrac{g_m}{2\pi [C_\pi + C_\mu]}$

⇒ Defining the unity gain freq. is the freq. at which gain falls down to '1'. (ω_t).

$$\left|\frac{I_c}{I_b}\right| = \frac{g_m r_\pi}{\sqrt{1 + [\omega r_\pi [C_\pi + C_\mu]]^2}}$$

⇒ At $\omega = \omega_t$ ⇒ $\left|\dfrac{I_c}{I_b}\right| = 1$.

$$1 = \frac{g_m \cdot \cancel{r_\pi}}{\omega_t \cancel{r_\pi} [C_\pi + C_\mu]}$$

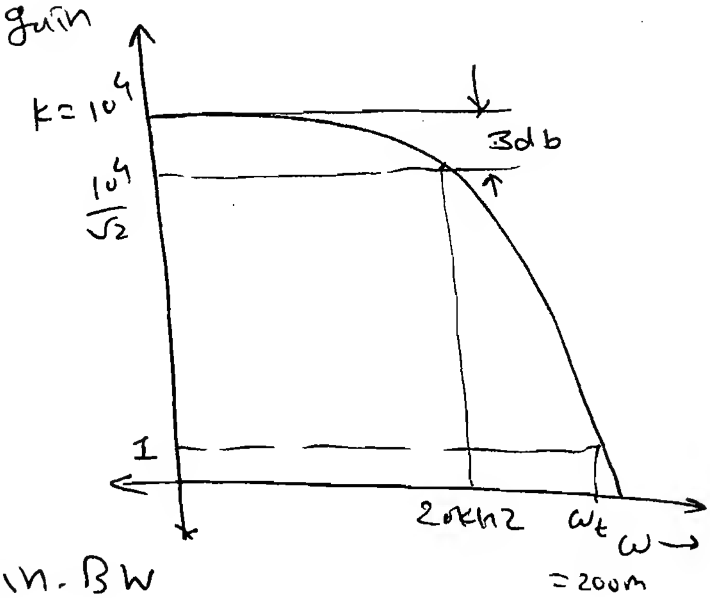
$\therefore \omega_t = \dfrac{g_m}{C_\pi + C_\mu}$ ⇒ $C_\pi + C_\mu = \dfrac{g_m}{2\pi f_t}$

$\therefore \boxed{f_t = \dfrac{g_m}{2\pi [C_\pi + C_\mu]}}$ ⇒ $\boxed{C_\pi = \dfrac{g_m}{2\pi f_t}}$

⇒ $\boxed{f_t = K \cdot f_{3db}}$

unity gain freq. = Gain BW.

Ex-1 An op-amp has unity gain freq. of 200 MHz with a gain of 80dB. Find the 3db BW.



Ans:

$$\text{Gain}_{db} = 20 \log \text{Gain}.$$

$$80 = 20 \log \text{Gain}$$

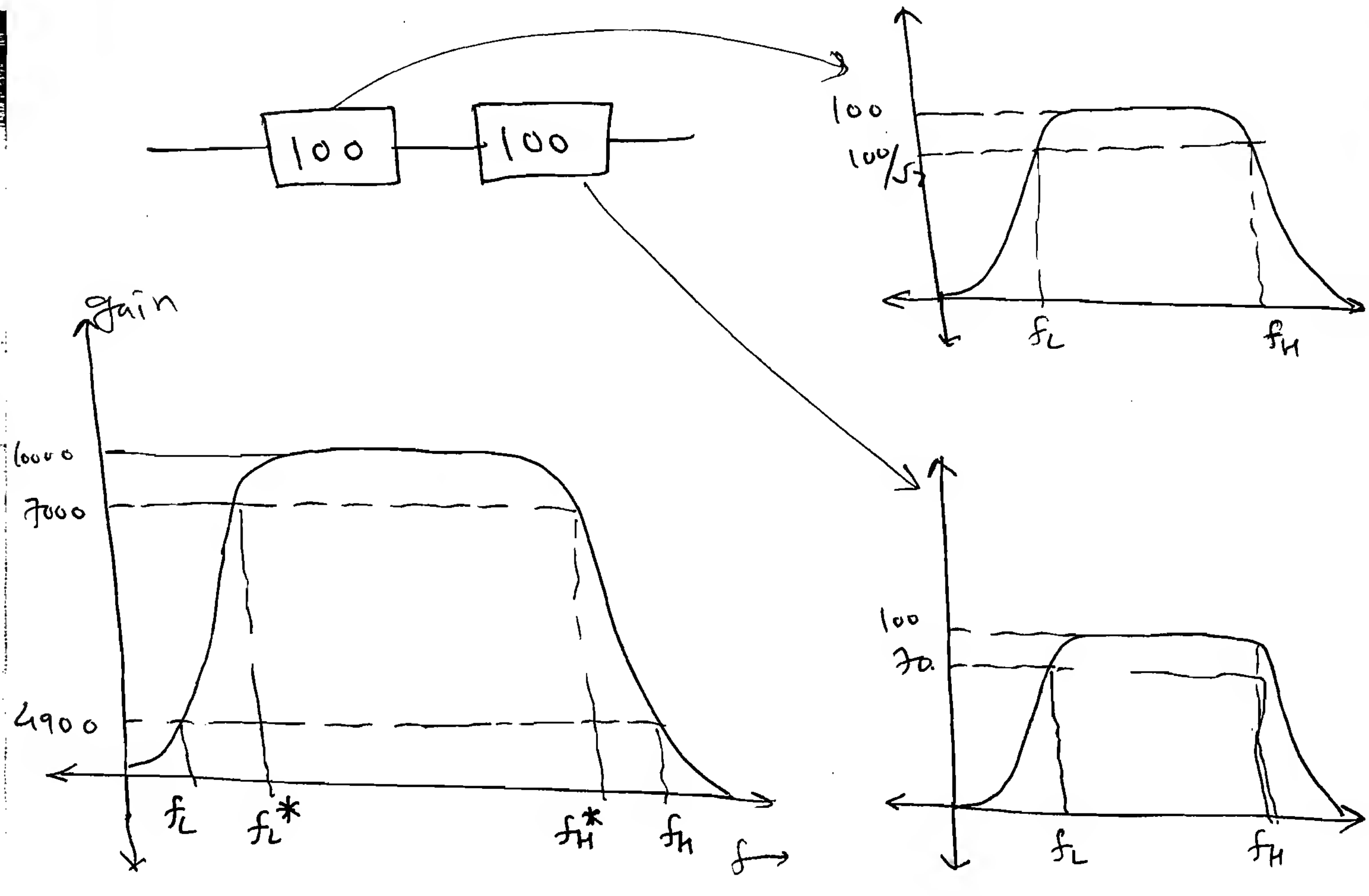
$$\text{Gain} = 10^4$$

→ unity gain freq. = Gain . BW

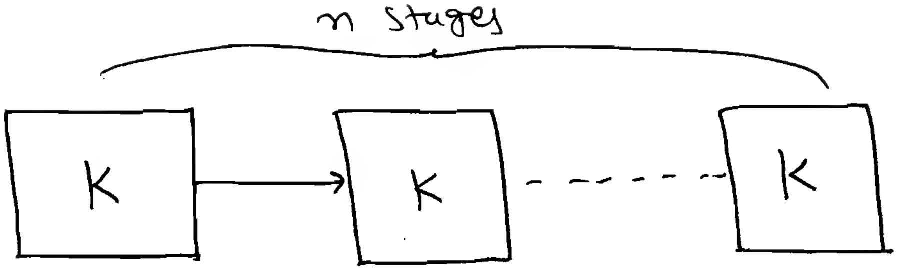
$$200 \times 10^6 = 10^4 \times BW$$

$$\therefore \boxed{BW = 20 kHz}$$

*



$\Rightarrow$



$\Rightarrow$ LPF $\quad \dfrac{K}{1+s\tau} = \dfrac{K}{1+\dfrac{s}{\omega_{3db}}} = \left| \dfrac{K}{1+j\dfrac{\omega}{\omega_{3db}}} \right| = \dfrac{K}{\sqrt{1+\left(\dfrac{\omega}{\omega_{3db}}\right)^2}}$

for single stage $\quad \dfrac{K}{\sqrt{1+\left(\dfrac{\omega}{\omega_{3db}}\right)^2}} = \dfrac{K}{\sqrt{2}}$.

for n stages.

$$\left[\frac{K}{\sqrt{1+\left(\frac{\omega}{\omega_{3dB}}\right)^2}}\right]^n = \frac{K^n}{\sqrt{2}}.$$

$$\boxed{W_{H\,total} = \omega_H\sqrt{2^{\frac{1}{n}}-1}}$$

$$\boxed{W_{L\,total} = \frac{W_L}{\sqrt{2^{\frac{1}{n}}-1}}}$$

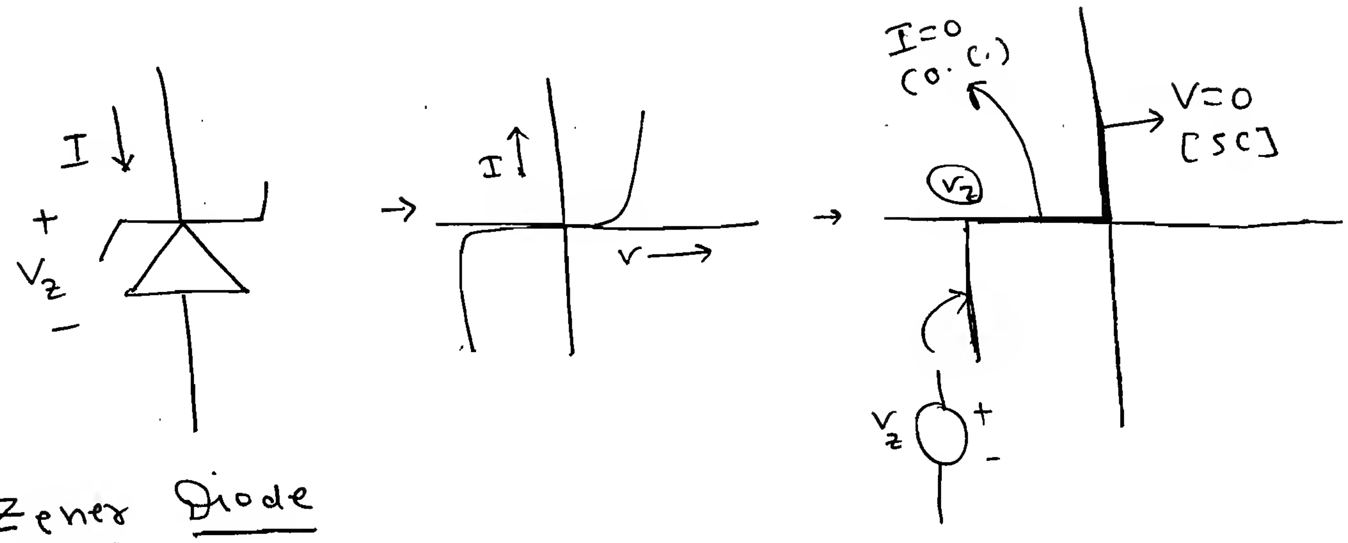
$\rightarrow$ for $n=2$

$\omega_{H\,total} = 0.6\,\omega_H$.

$W_{L\,total} = 1.55\,\omega_L$.

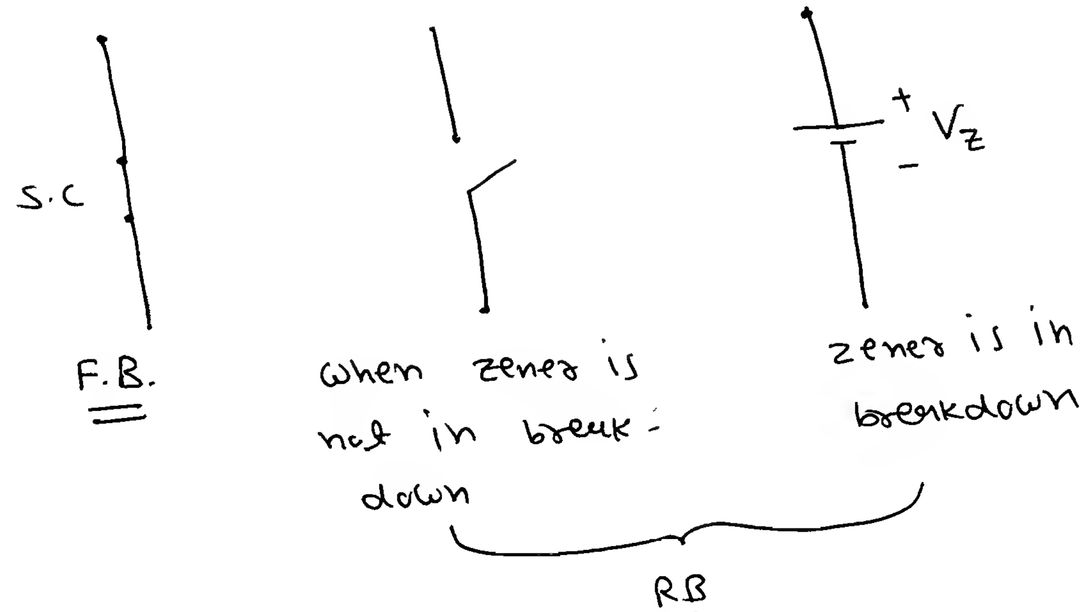
☆ Voltage Regulators:

⇒



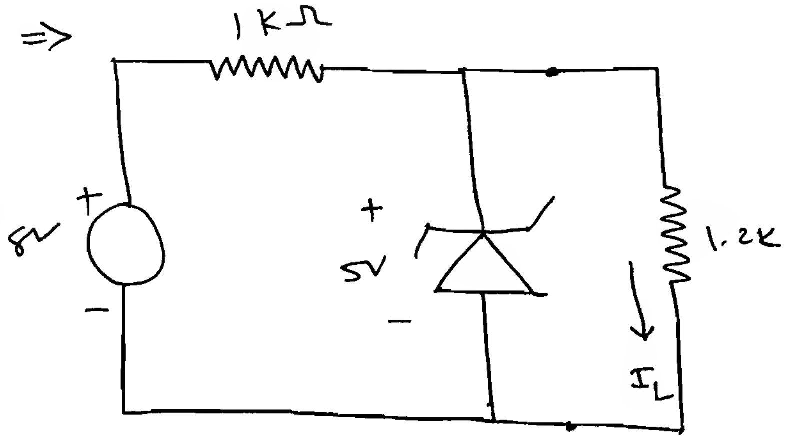
Zener Diode

⇒



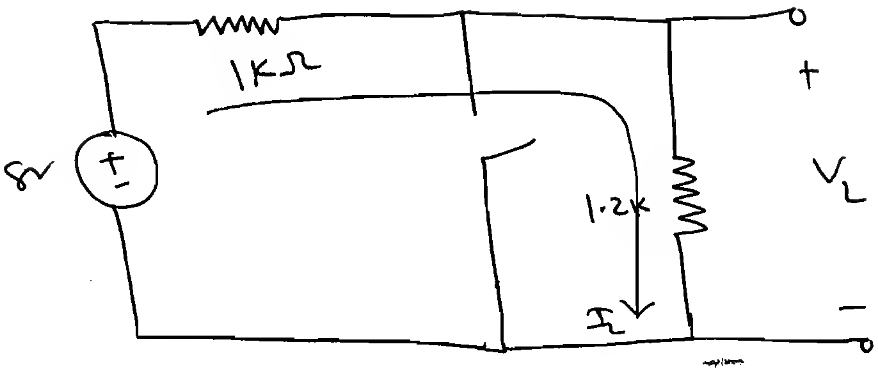
⇒ **Zener as a Voltage Regulator:**

⇒



⇒ First open ckt the zener and calculate the terminal volltage. i.e. check weither zener

is in breakdown or not.



$V_L = \frac{1.2K}{2.2K} \times 8$

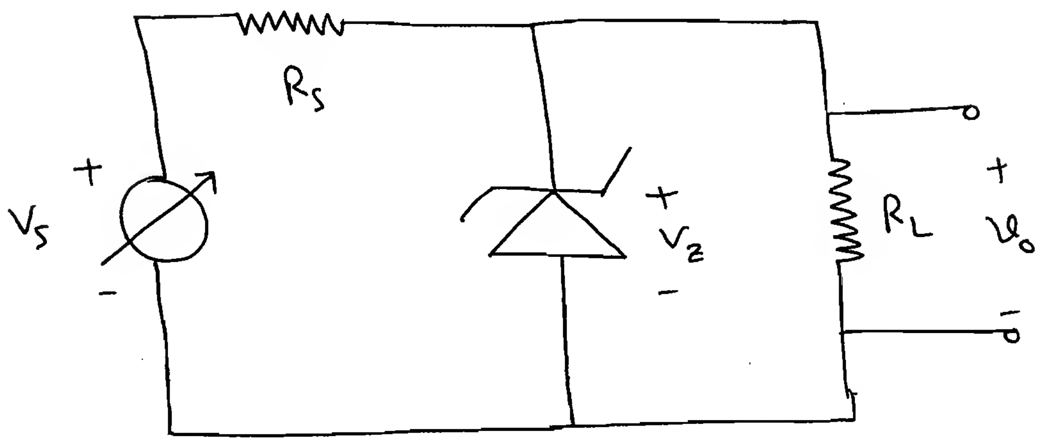
$= 4.3\,V < V_Z$

$\Rightarrow$ zener is not in breakdown.

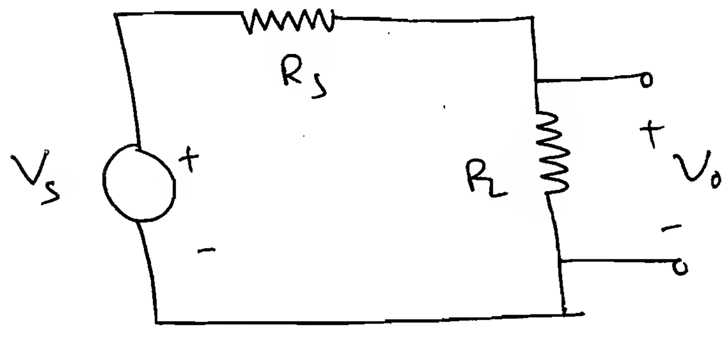
$\therefore \quad I_L = \frac{8}{2.2K}$

$\therefore \quad \boxed{I_L = 3.64\ mA}$

*



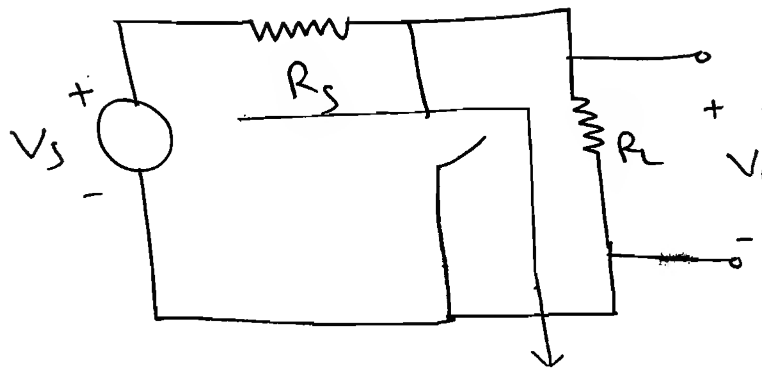
$\Downarrow$



$V_o = \left(\frac{R_L}{R_L + R_s} \right) \times V_s$

case-(i)

⇒ if $V_L < V_Z$ ⇒ Zener is not in Breakdown.

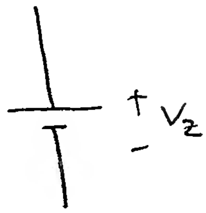


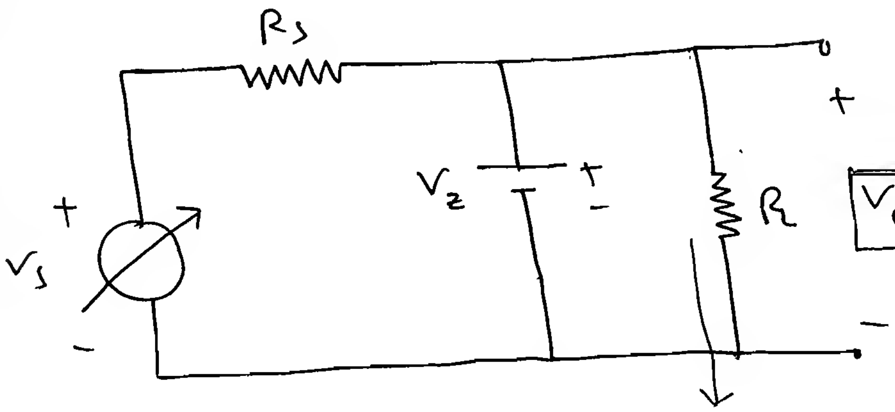
$$V_o = \frac{V_S \cdot R_L}{R_L + R_S}$$

$$I_L = \frac{V_S}{R_L + R_S}.$$

Case-ii

⇒ if $V_L > V_Z$ ⇒ Zener is in breakdown.

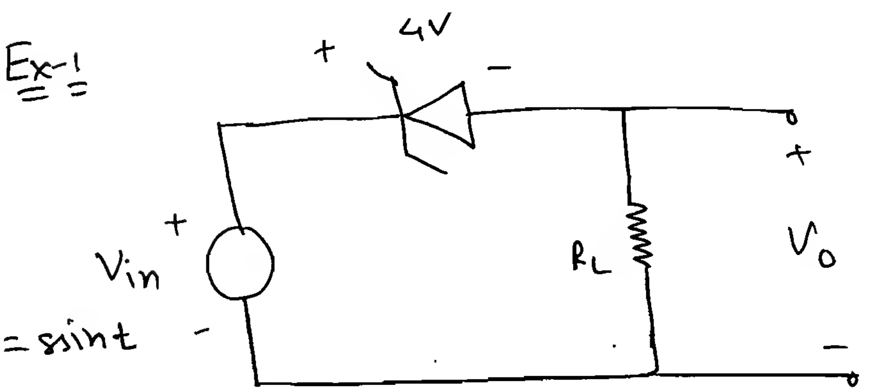




$$\boxed{V_o = V_Z}$$

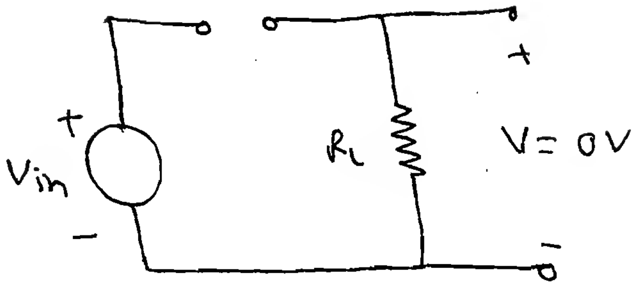
$$I_L = \frac{V_Z}{R_L}.$$

Ex-1

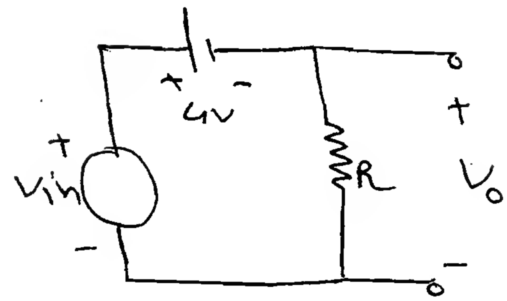


Sketch the output waveform V_o.

(i) $0 \le V_{in} \le 4V$

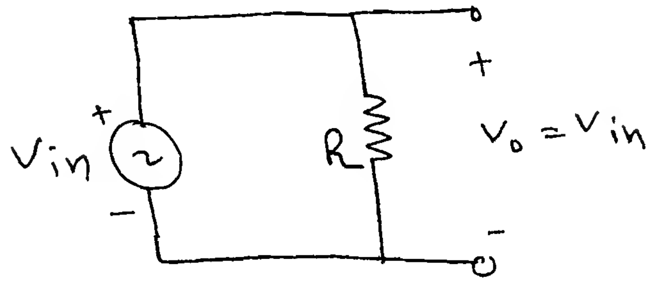


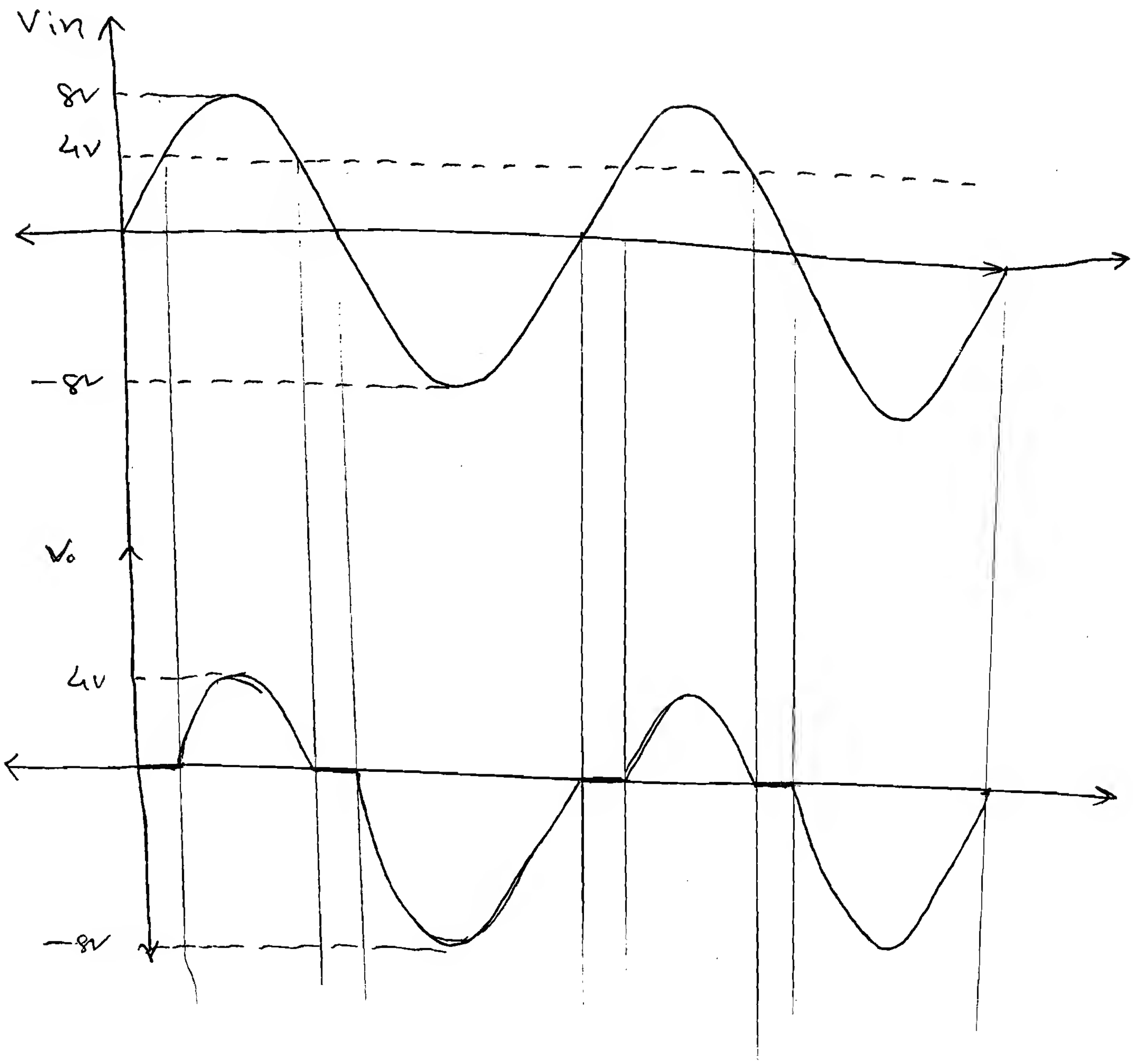
(ii) $4 \le V_{in} \le 8V$



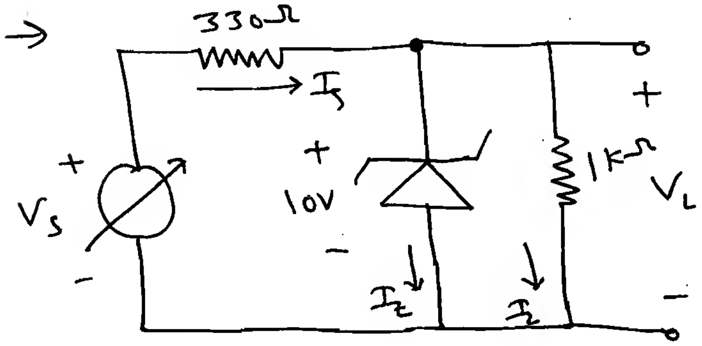
$V_o = V_{in} - 4.$

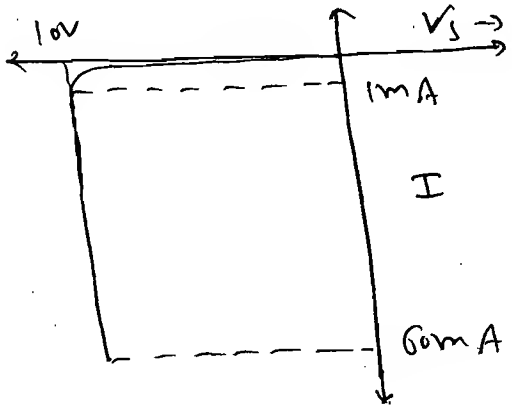
(iii) neg cycle:





Ex-1 Find the Range of Voltage Source V_s to which the zener is satisfactory on if the minimum current is 1mA and the maximum current zener can safely handle a 60 mA.





Ans: $V_Z = 10V$,

$I_s = I_Z + I_L$

$$\frac{V_s - 10}{330} = I_s.$$

$$\therefore \boxed{V_s = 10 + 330 \cdot I_s.}$$

$V_s \uparrow$

$I_s \uparrow = (I_Z + I_L)$ const

① $I_Z = 1mA$.

$\therefore I_L = \frac{10}{1k} = 10mA$

$\therefore I_s = 1m + 10m = 11mA$.

$\therefore V_s = 10 + (330 \times 11m)$

$\boxed{V_s = 13.3\,V}$

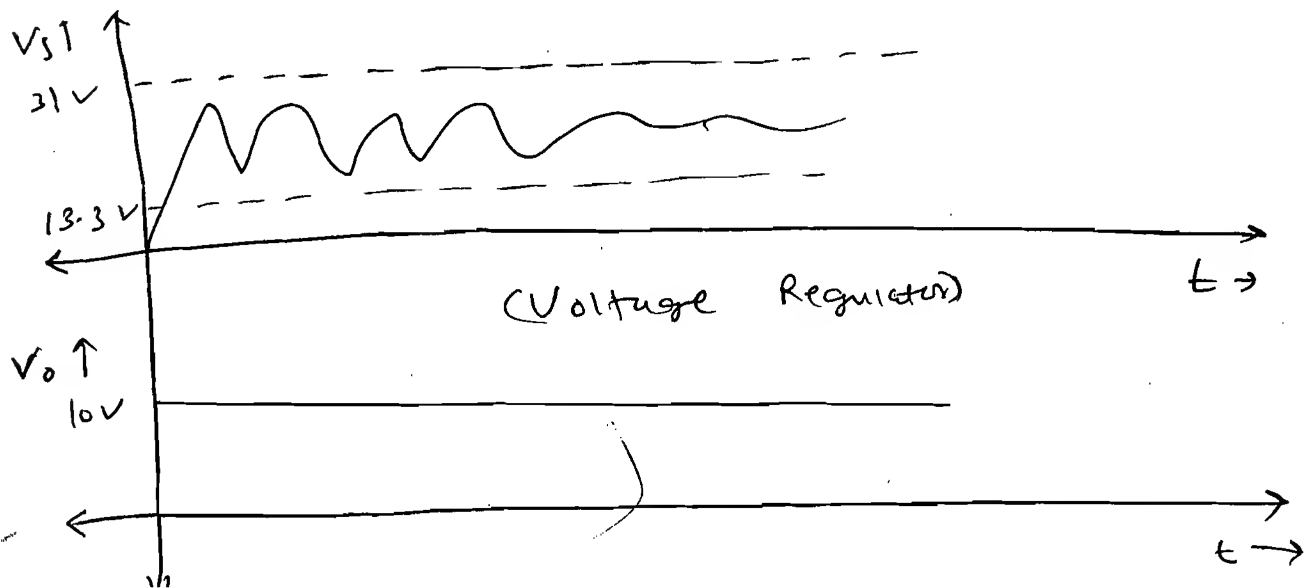
② $I_Z = 60mA$

$\therefore I_s = 10m + 60m = 70mA$

$\therefore V_s = 10 + (330 \times 70m)$.

$\boxed{V_s = 33.1\,V}$

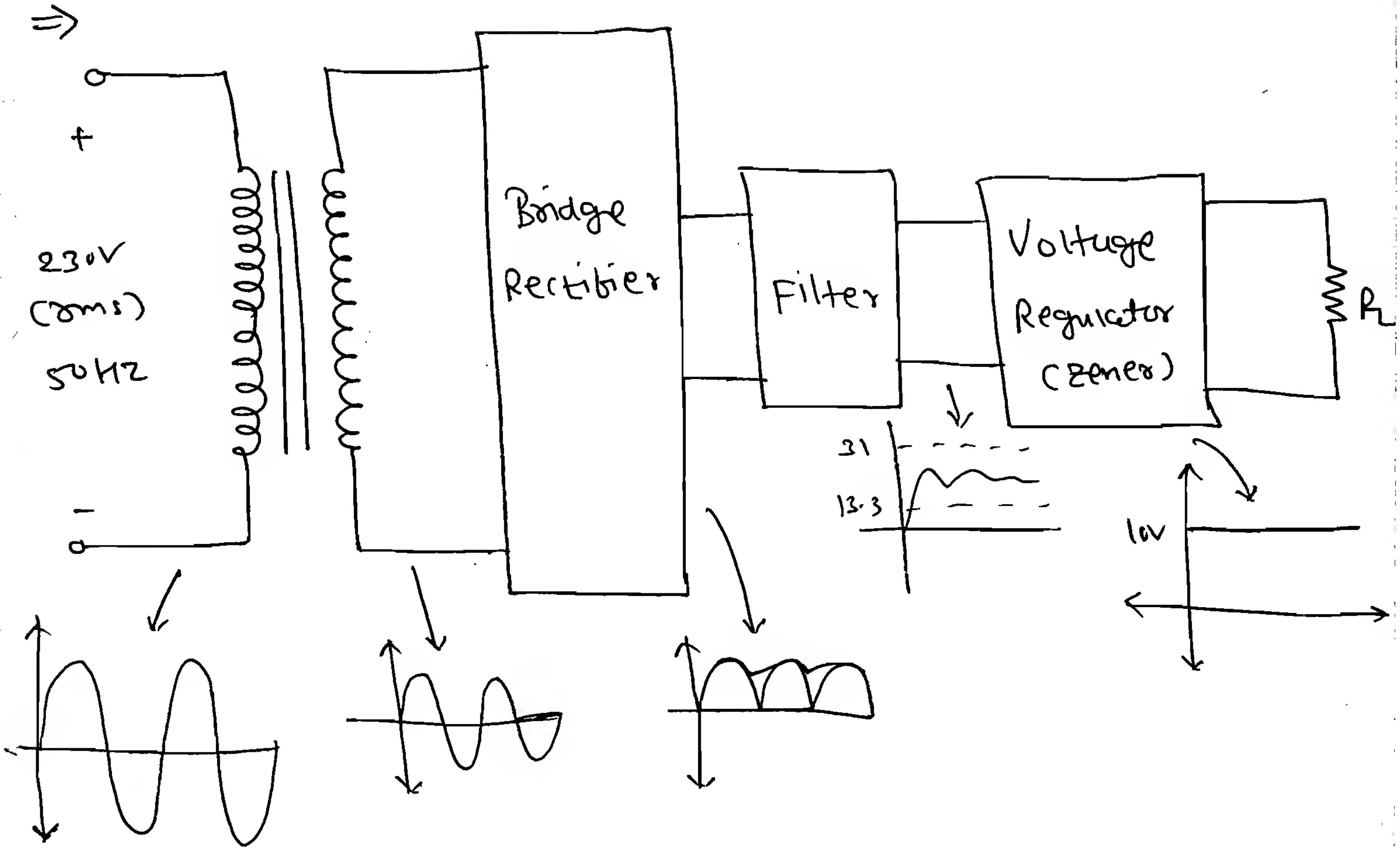
So, V_o range $\boxed{V_o : 13.3V \text{ to } 31V}$



(Voltage Regulator)

☆ Simplify Block Diagram of a DC Power Supply.

⇒



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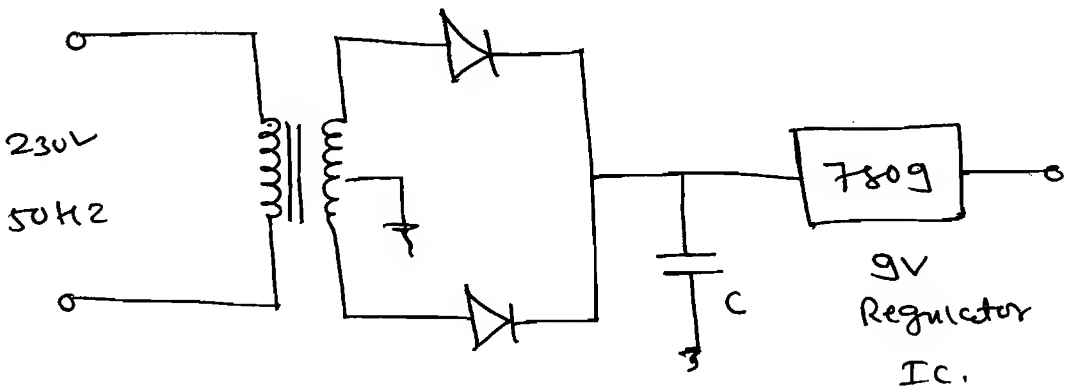

7809 → 9V

7810 → 10V

7812 → 12V

7909 → -9V

7910 → -10V

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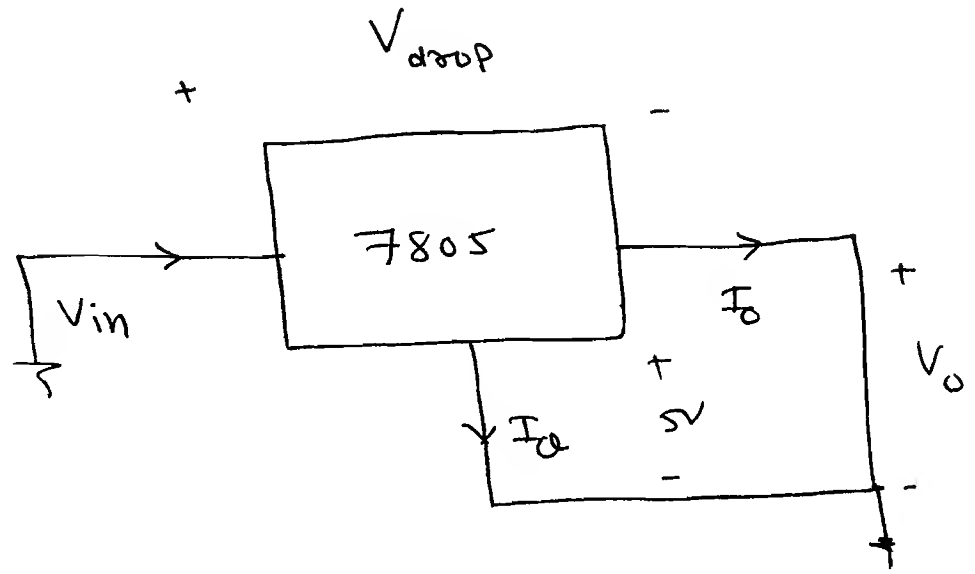
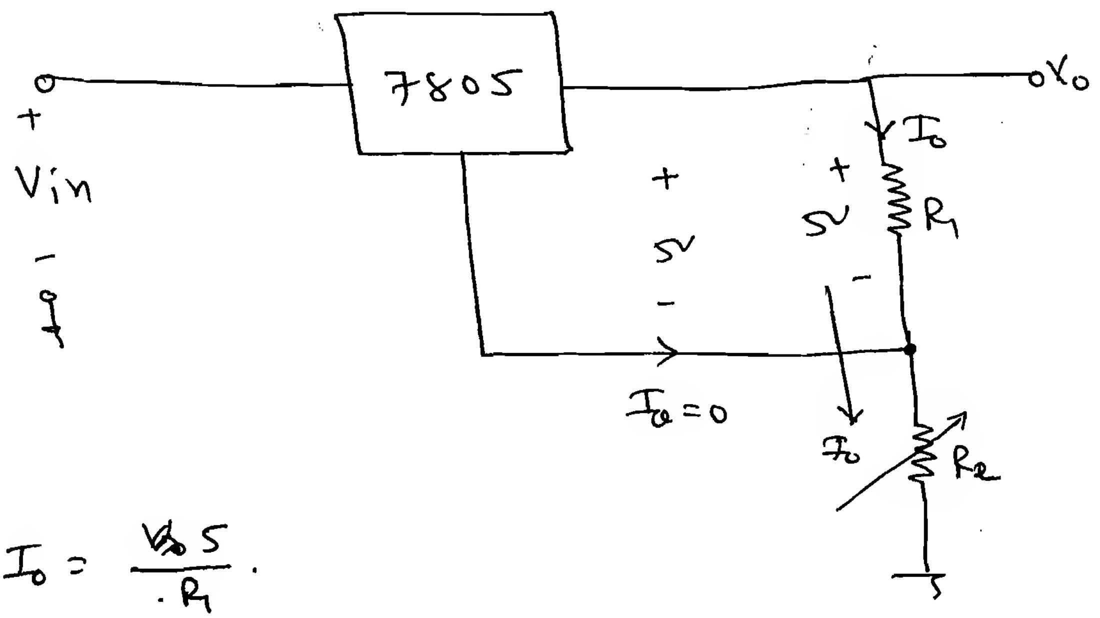


$\Rightarrow$ KCL, $I_{in} = I_Q + I_o$.

$\Rightarrow$ KVL, $V_{in} = V_{drop} + V_o$

* Increase the Voltage range of 7805 from 5V to 12 V (neglect the Quiescent current I_Q and the drop across the I_Q is 2V.



$\rightarrow I_o = \frac{5}{R_1}$.

$\therefore V_o = I_o (R_1 + R_2)$.

$\therefore \quad V_0 = \frac{5}{R_1}\left(R_1 + \frac{R_2}{}\right)$

$\therefore \quad V_0 = \left(1 + \frac{R_2}{R_1}\right)5$

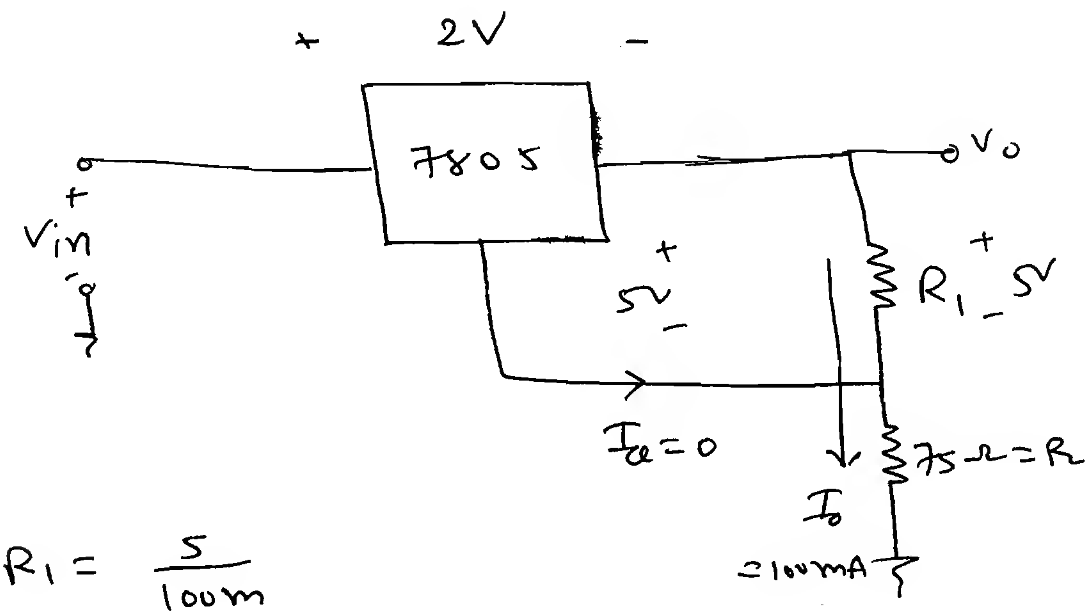
let, $R_1 = 1\,k\Omega$.

V_0 range : 5 to 12 V

R_2 range : 0Ω to $1.4\,k\Omega$

<u>IES</u>
<u>Ex-1</u> Design a 7805 for a $75\,\Omega$ Load drawing a current of 100mA. A drop across the IC is 2V and neglect the quescent current.

<u>Ans:</u>



$\therefore \quad R_1 = \frac{5}{100m}$

$\therefore \quad \boxed{R_1 = 50\,\Omega}$

$\therefore \quad V_{in\,min} = 12.5 + 2V$

$= V_0 + V_{drop}$

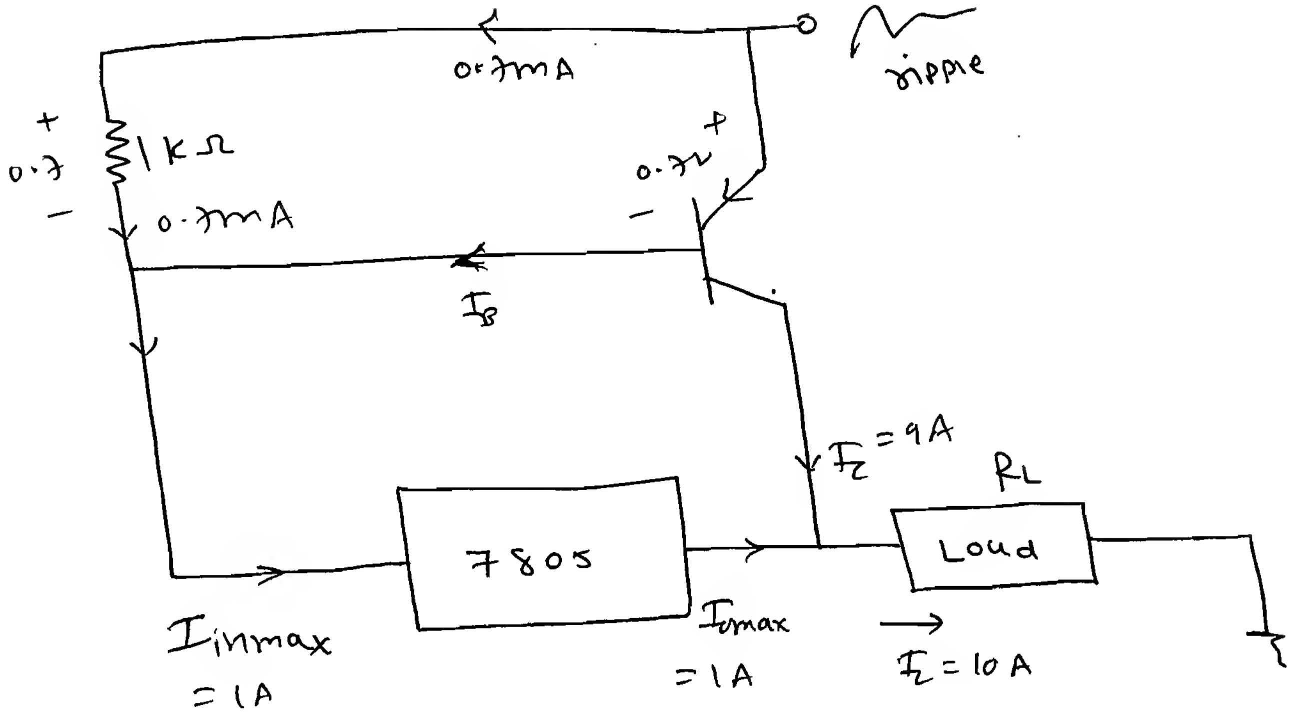
$\therefore \quad V_0 = I_0 (R_1 + R_2)$.

$\therefore \quad V_0 = 100m(125)$.

$\boxed{V_0 = 12.5V}$

$\therefore \quad \boxed{V_{in\,min} = 14.5\ V}$

* Increasing Current range of Voltage regulator:



$\Rightarrow \quad I_{inmax} = 0.7m + I_B$

$\rightarrow \quad \boxed{I_B \approx I_{inmax} = 1\ A.}$

$I_L = I_{omax} + I_C.$

$I_L = \beta I_B + I_{omax}$

$\therefore \quad I_L = \beta I_{in} + I_{omax}$

$\therefore \quad I_L = (\beta+1)\ I_o.$

$I_o \simeq I_{in}.$

$\therefore \quad I_{omax} = 1A.$

$\beta = 9$

$\Rightarrow \quad I_L = (9+1)\ 1$

$\boxed{I_L = 10A}$

Disadvantages:

(i) 0.7 V drop across transistor

(ii) If we want different output voltage we have to chang the zener diode.

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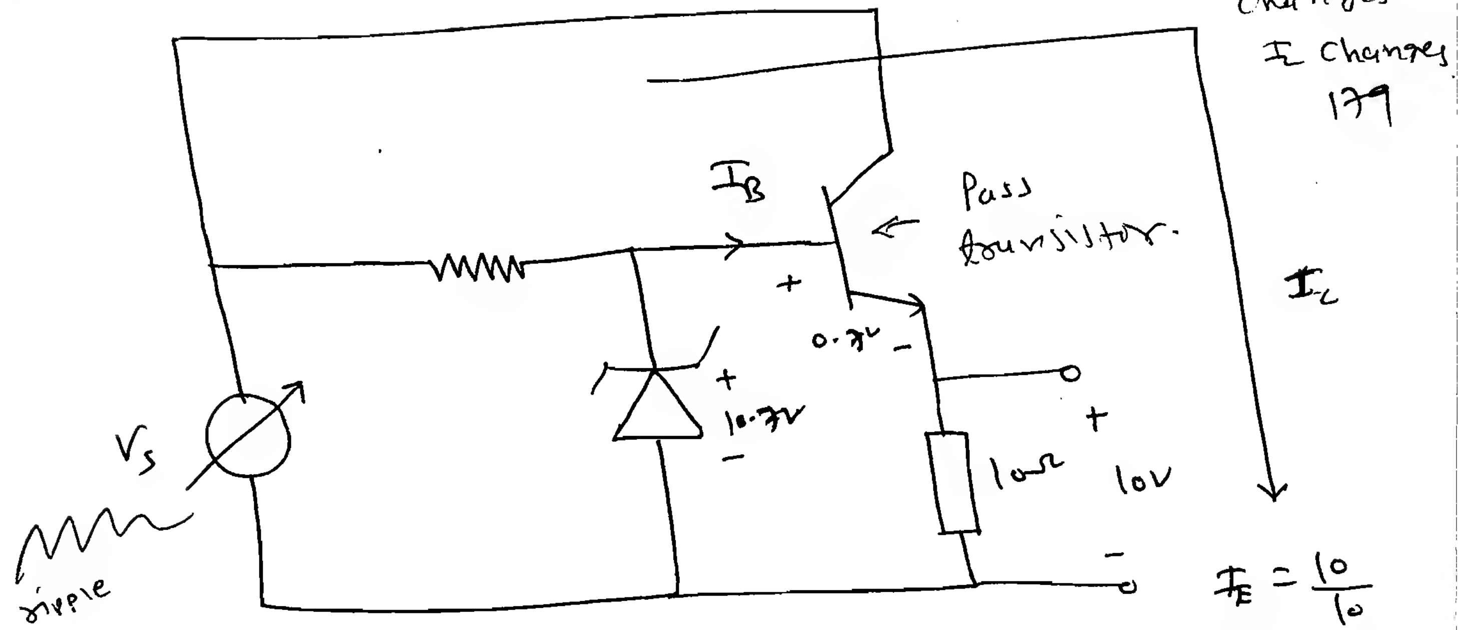
when Load Changes I_L Changes

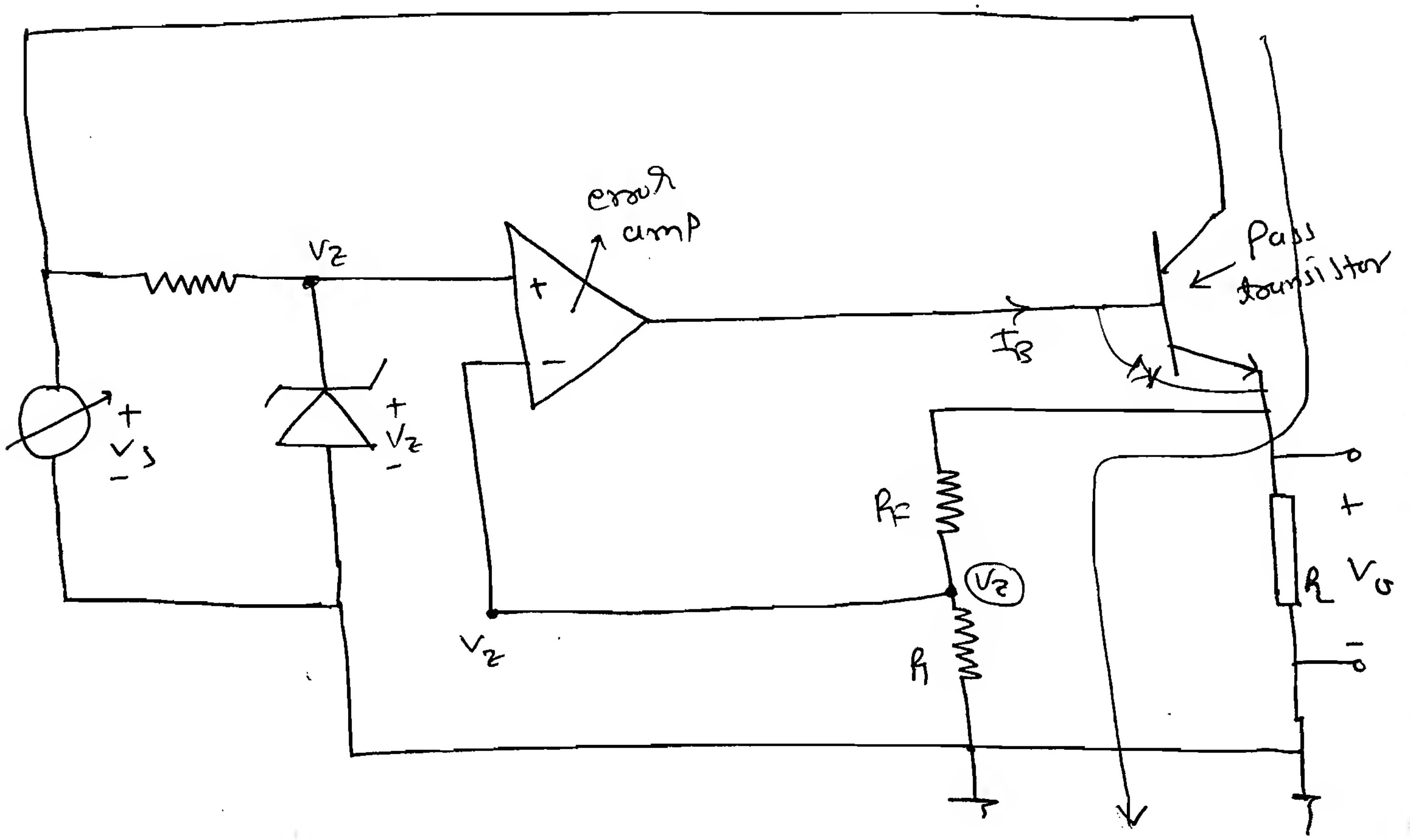


$I_E = \frac{10}{10}$

$\boxed{I_E = 1A}$

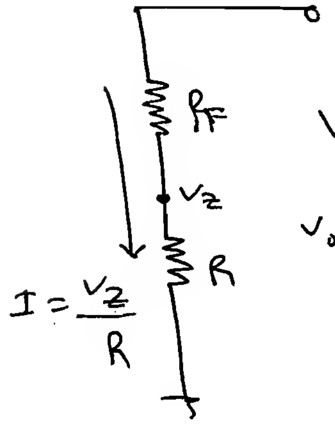
Increasing the current range

* Increase Voltage range of Zener by error Amp. along with increase current range by Pass transistor.



$$\Rightarrow \quad \frac{V_z - V_0}{R_F} + \frac{V_z}{R_1} = 0.$$

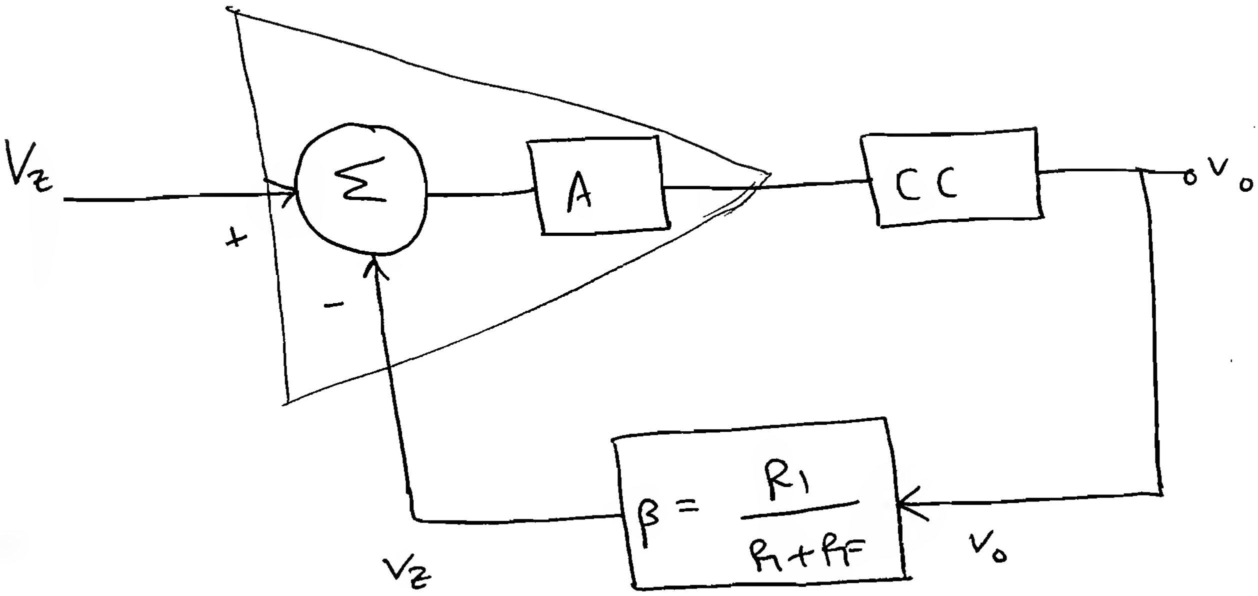
$$\therefore \quad \boxed{V_0 = \left(1 + \frac{R_F}{R_1}\right) V_z}$$



$$V_0 = I_0 (R_F + R_1)$$

$$V_0 = \frac{V_z}{R}(R_F + R_1)$$

* General Configuration:



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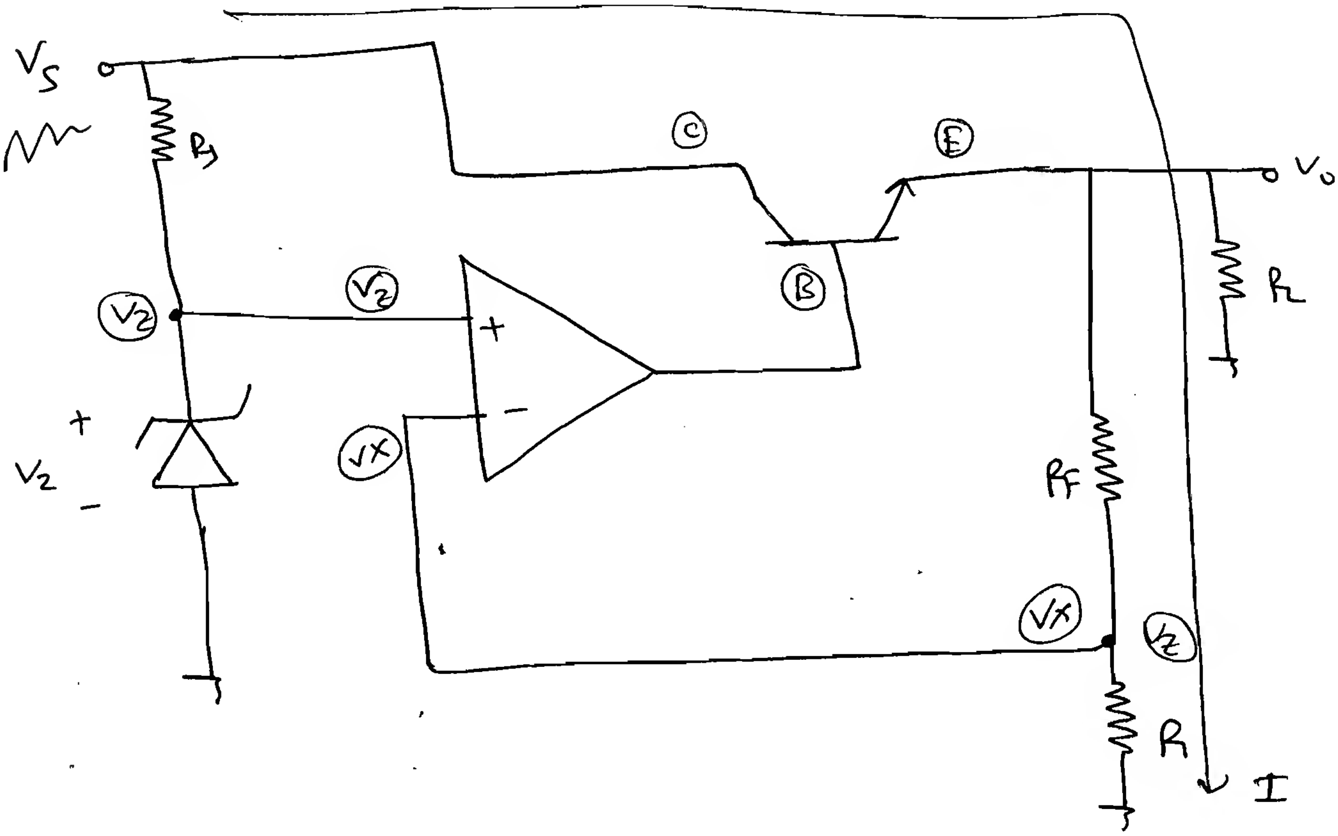
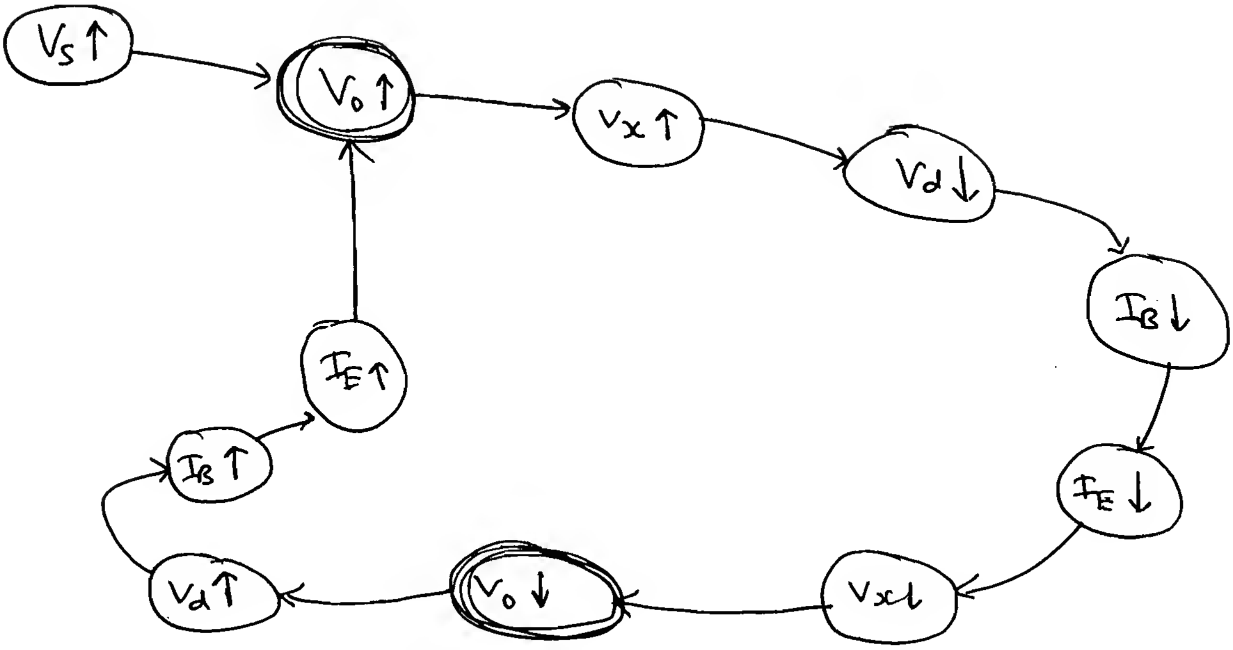


$$\Rightarrow \quad I = \frac{V_Z}{R_1}.$$

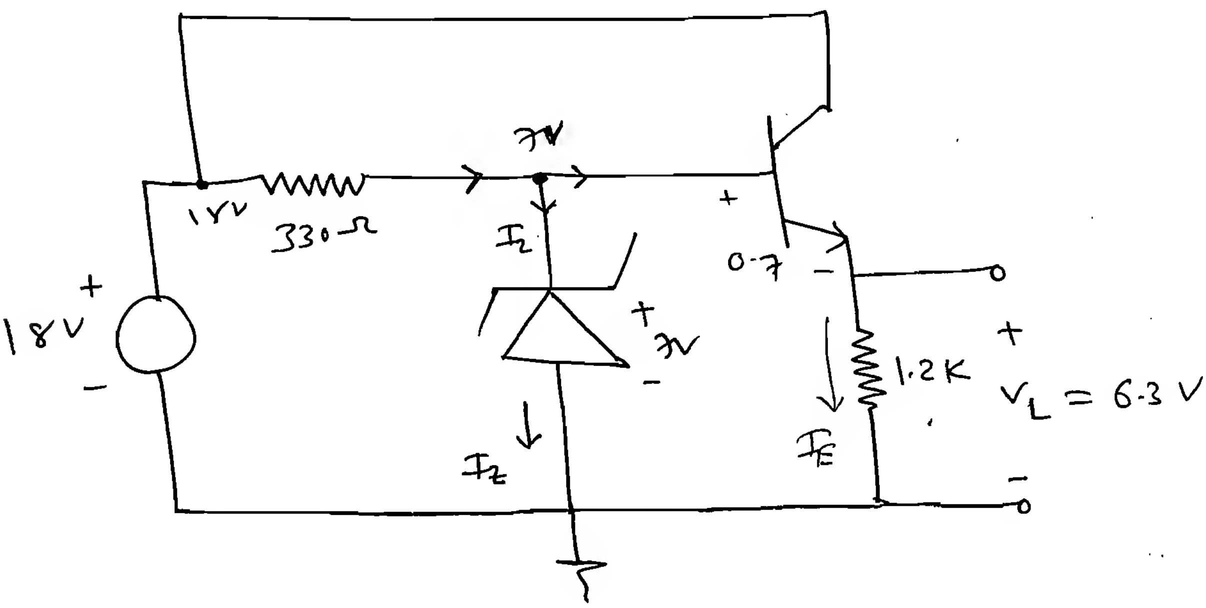
$$\therefore \quad V_o = I\,(R_1 + R_F).$$

$$\therefore \quad V_o = \frac{V_Z}{R_1}\,(R_1 + R_F).$$

$$\therefore \quad V_o = V_Z\left(1 + \frac{R_F}{R_1}\right).$$



Ex-1 Given $\beta = 100$. Calculate the Zener current I_Z.



Ans: $I_E = \frac{V_E}{R_E} = \frac{6.3}{1.2k}$

$$\boxed{I_E = 5.25\,mA}$$

$I_B = \frac{I_E}{(\beta+1)}$

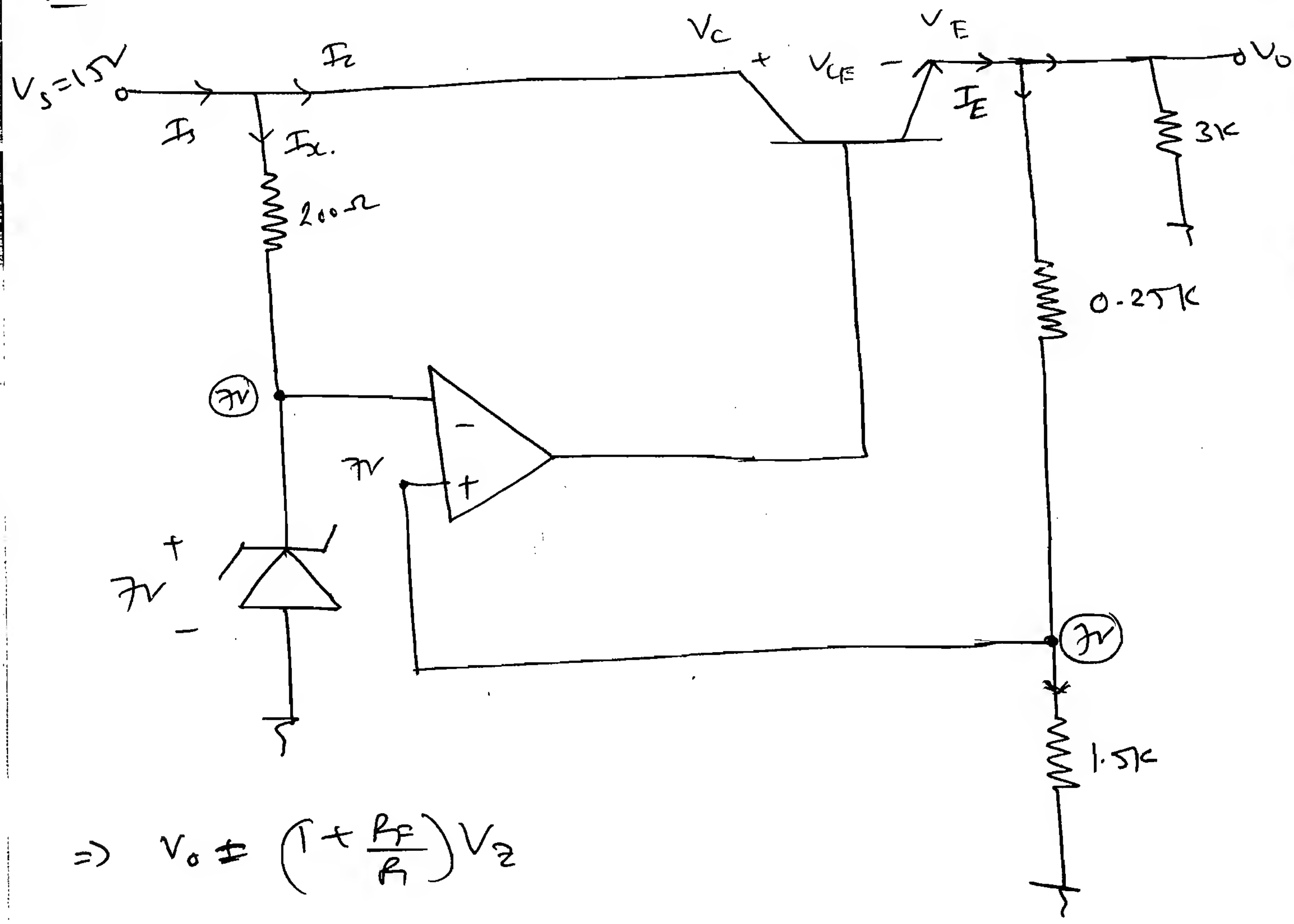
$$\boxed{I_B = 51.98\,\mu A}$$

By KCL, NODA

$$\frac{18-7}{330} = I_Z + I_B$$

$$\therefore \boxed{I_Z = 33.28\,mA}$$

Ex-1 Calculate the Power dissipation if $\beta = 100$.



$\Rightarrow V_o = \left(1 + \frac{R_F}{R_1}\right) V_Z$

$$\Rightarrow V_o = \left(1 + \frac{0.25}{1.25}\right) 7$$

$$\boxed{V_o = 8.4\,V = V_E}$$

$$I_S = \frac{15-7}{200} + I_C$$

$$\rightarrow \boxed{I_S = 47.52\,mA}$$

By NDA

$$I_E = \frac{V_o}{1.75K} + \frac{V_o}{3K}$$

$$\therefore I_E = \frac{8.4}{1.75K} + \frac{8.4}{3K}$$

$$\rightarrow \boxed{V_C = 15V}$$

$$\therefore I_E = 7.6\,mA$$

$$I_C = \left(\frac{\beta}{\beta+1}\right) I_E$$

$$\therefore \boxed{I_C = 7.5247}$$

$\therefore$ Power dissipation

$$P_D = V_{CE} \times I_C$$

$$= (V_C - V_E) \times I_C$$

$$= (15 - 8.4) \times 7.5247$$

$$\rightarrow \boxed{P_D = 49.66\,mW}$$

* Error Amplifier using BJT:

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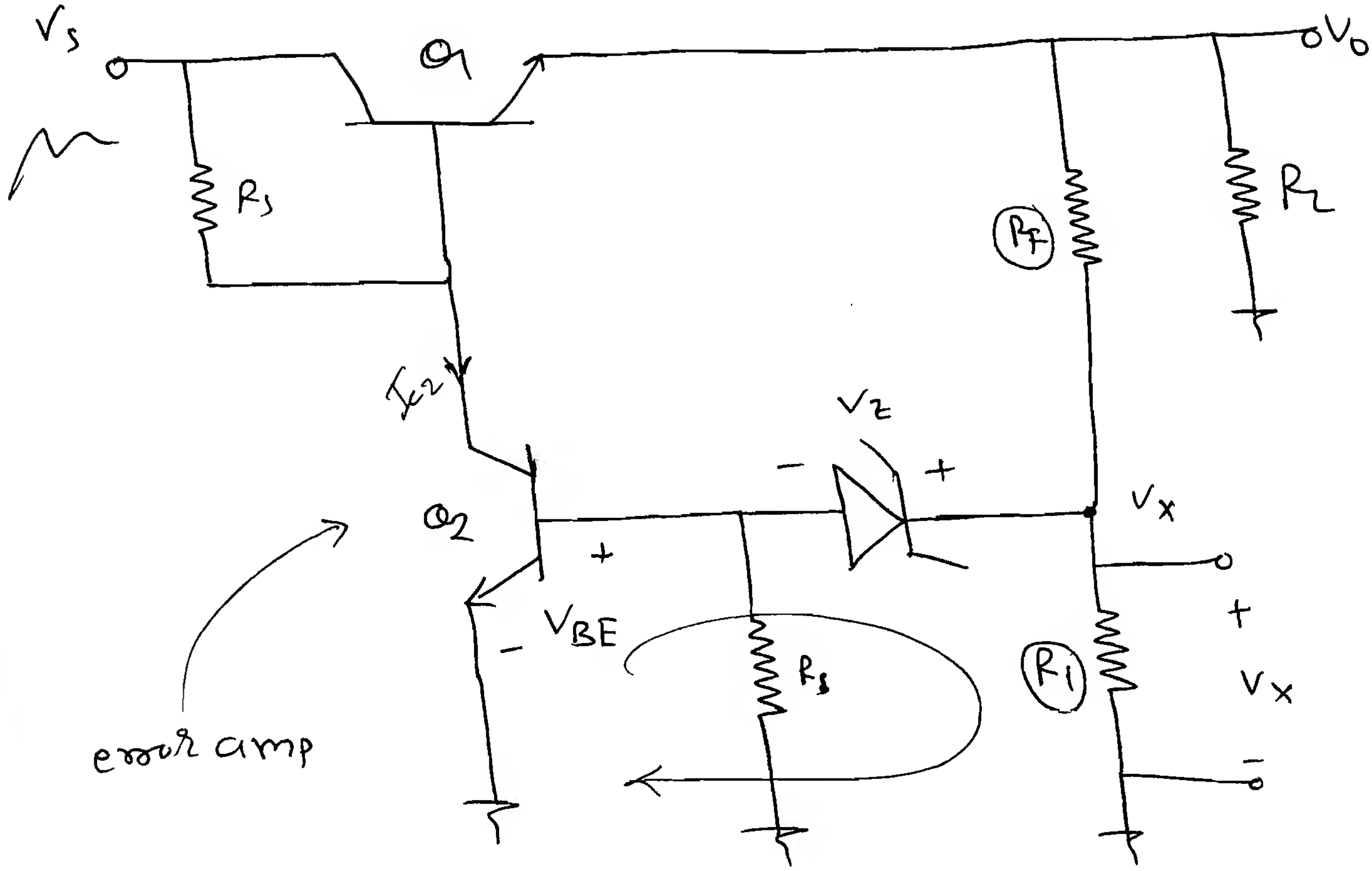
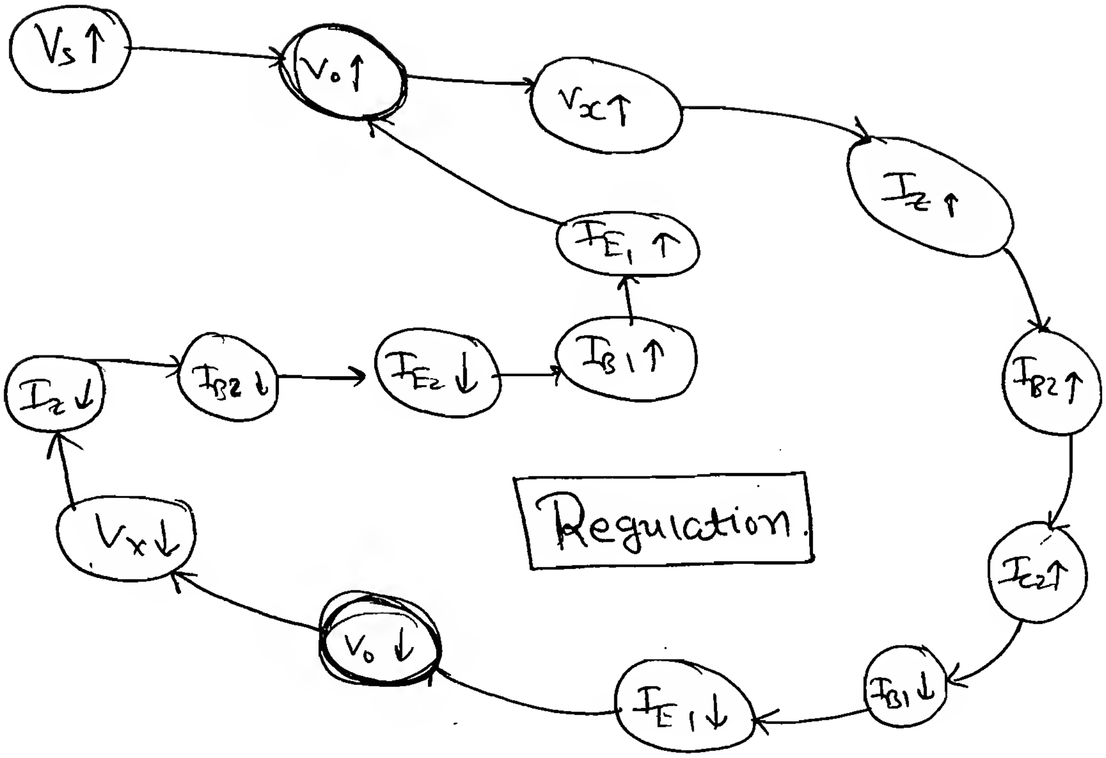


$$\therefore \quad V_x = \left(\frac{R_1}{R_1 + R_F}\right) V_o.$$

By KVL $\quad V_{BE} + V_Z = V_X.$

$$\therefore \quad V_o = \left(1 + \frac{R_F}{R_1}\right) V_X.$$

$$\therefore \quad \boxed{V_o = \left(1 + \frac{R_F}{R_1}\right)(V_{BE} + V_Z).}$$



* Short circuit Protection of Voltage Regulator:

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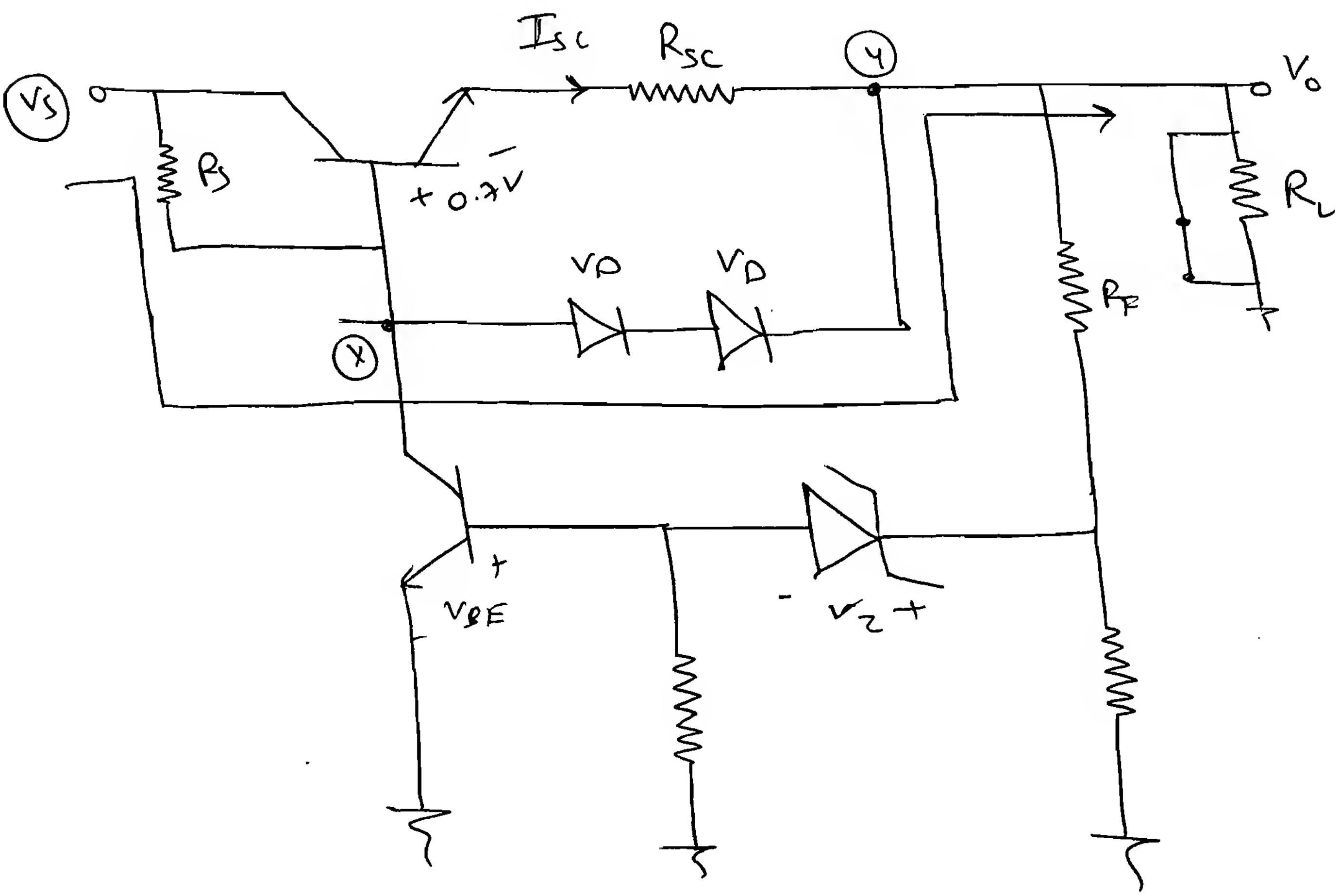

$$\Rightarrow \quad V_{XY} = 0.7 + I_{sc} \cdot R_{sc} = V_D + V_D.$$

$$\therefore \quad \boxed{R_{sc} = \frac{0.7}{I_{sc}}}$$

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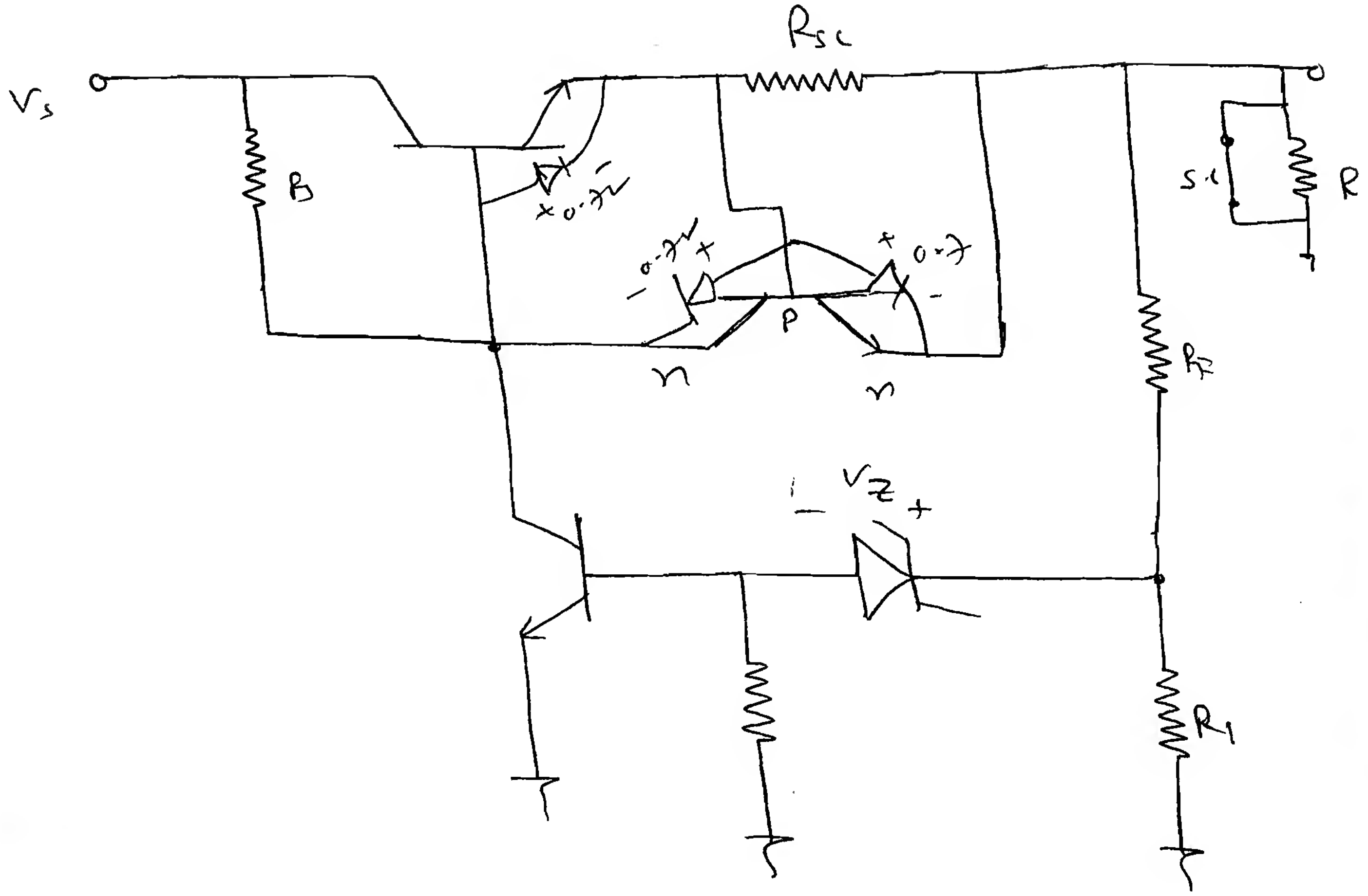

⇒ * Foldback Current limitting of Voltage Regulators:

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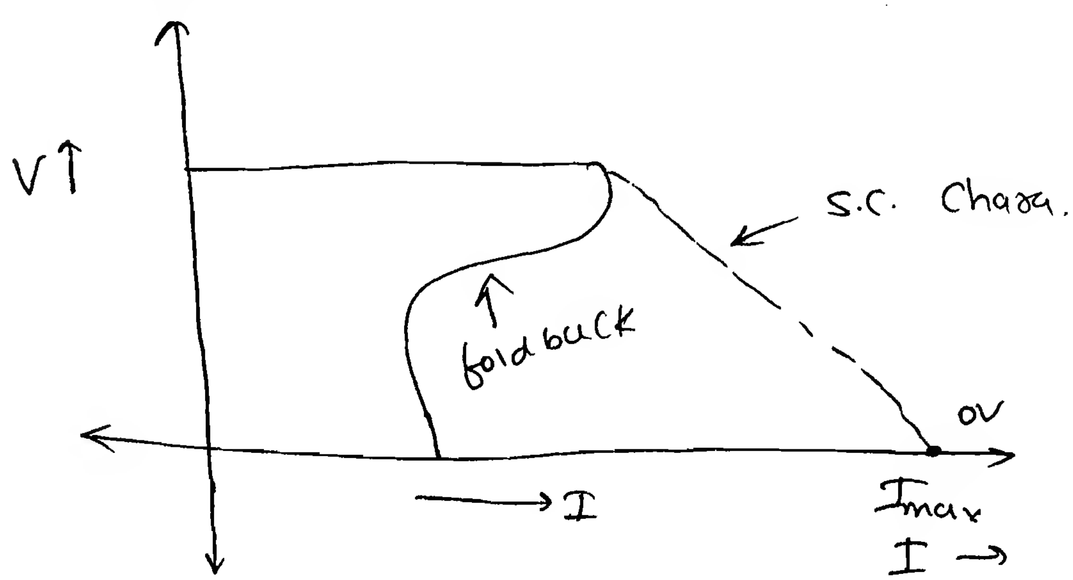

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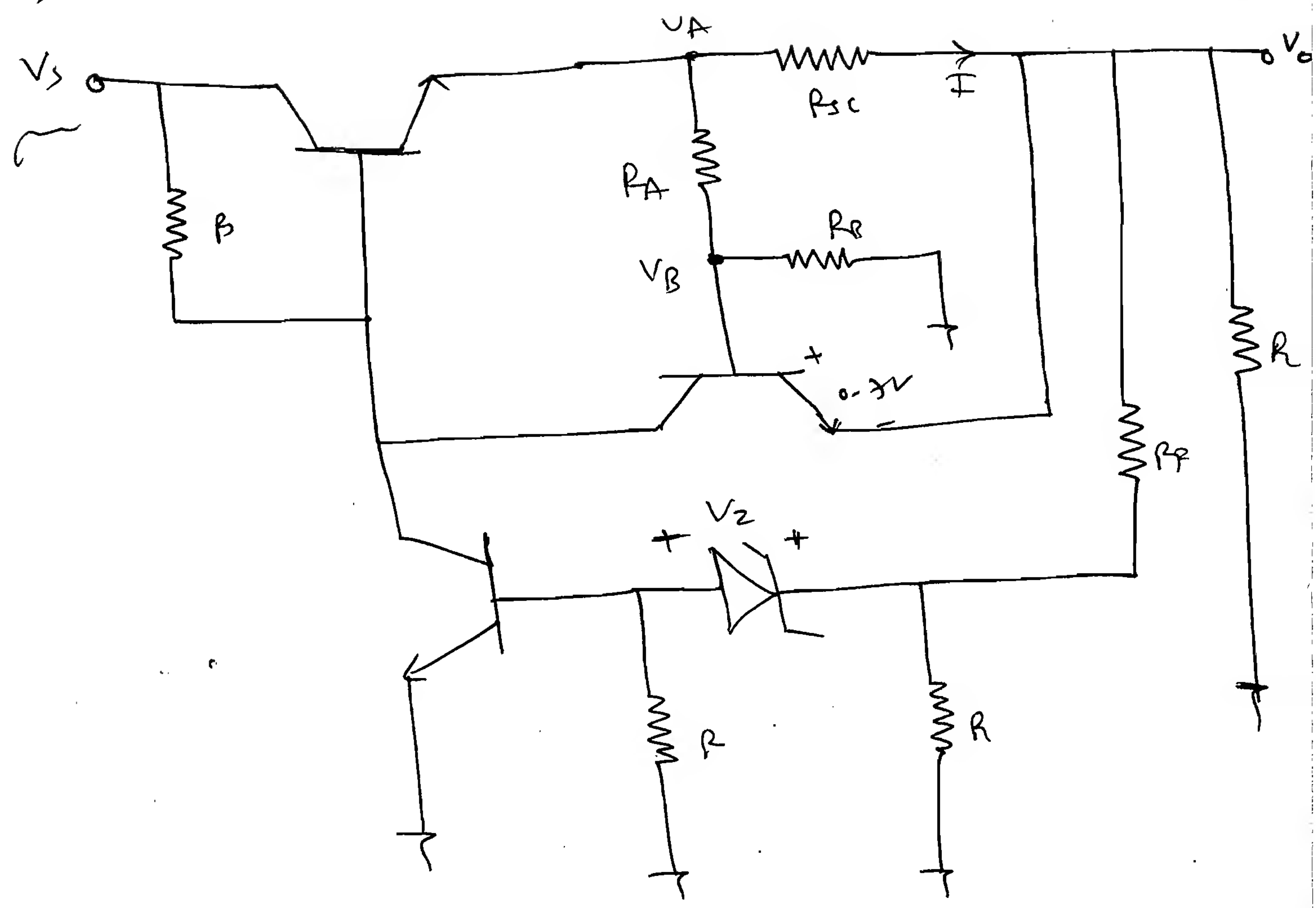

$$\Rightarrow \quad V_B = \left(\frac{R_B}{R_A+R_B}\right) V_A = 0.7 + V_0$$

$$\Rightarrow \quad V_A = \left(1 + \frac{R_A}{R_B}\right) V_B.$$

$$\rightarrow \quad V_A = IR_L + V_o = \left(1 + \frac{R_A}{R_B}\right)(0.7 + V_0).$$

$$\therefore \quad I_{nor} = \frac{\left(1 + \frac{R_A}{R_B}\right)(0.7 + V_0) - V_0}{R_L}.$$

During S.C. $V_0 = 0V$.

$$\therefore \quad I_{sc} = I = \left(1 + \frac{R_A}{R_B}\right) 0.7.$$

$$\boxed{I_{sc} < I_{norm.}}$$

*